G 14514 ■ 15th year ■ September 2007 3/2007
Quarterly Information of the Forschungsgemeinschaft Funk e.V.

NEWS letter

Festschrift

15 years FGF

Network for Research and Information

FGF
Forschungsgemeinschaft Funk e.V.

15 years FGF Network for Research and Information

Index

Editorial

The Forschungsgemeinschaft Funk (FGF) celebrates a round anniversary, for the third time already: fifteen years ago, on September 1, 1992, the FGF was founded as a non-profit association. On the initiative of the Federal Ministry of Post and Telecommunication and the Minister, Dr. Christian Schwarz-Schilling, respectively, 16 institutions from the ranks of industry, network operators, associations, universities and the Ministry of Post brought the FGF into being with the aim to as far as possible objectify the debate over mobile radio and its possible biological effects – popularly called "electrosmog".

The „network for research and information" of the FGF is devoted to the biological effects of electromagnetic fields on humans and the environment. Looking back, the FGF has developed into an efficient institution financing research projects, but has also gained international reputation as a mediator of discussion and advice in the 15 years of its work. With its international workshops, jointly organized with the WHO, the European Union (COST action 281, EMF-NET) and other institutions like e.g. the Ministry of Environment of Baden-Württemberg and the Federal Office for Occupational Safety and Health, the FGF has created an internationally acknowledged platform for the exchange of data, facts and know-how on hot scientific topics.

In the information given to the public, media and politics, the FGF observes strict neutrality in the often very emotional discussion, i.e. it is committed only to scientific accurateness. Until today, the FGF has spent 10 million euros for research, i.e. for about 80 research projects. Among the members are numerous international companies, universities and authorities.

All this is a good reason for organizing a scientific symposium titled "15 years of FGF – Network for Research and Information" on the occasion of its 15th anniversary, followed by a celebration in the evening. 15 years of the Forschungsgemeinschaft Funk e. V. also stands for a 15-year struggle of understanding the question in our statutes: "Are high-frequency electromagnetic fields below valid limits a danger for humans and/or the environment?" Is it possible at all to find an objective answer to this question? In view of the many influential factors that rationally, but also emotionally affect the public discussion, the FGF has tried to remain independent of convictions and opinions and to orient exclusively to scientifically founded arguments.

The quality of scientific assertions depends on many factors, e.g. the comparability and reproducibility of research results, including a solid statistical evaluation, etc. Through its work the FGF has contributed to the improvement of research activities in the field of EMC, especially by:

- providing guidelines for scientifically accurate exposure experiments
- the description and definition of generic GSM and UMTS signals for experimental use
- the active support of the research agendas of the WHO and the EU.

The FGF early on pointed out the need and relevance of interdisciplinary cooperation and has successfully optimised the quality of scientific research by diligent design, performance and evaluation of results. By developing, supporting and financing different information databases the FGF made scientifically verified, peer-reviewed research results available to research institutions.

In the field of information provision the FGF has established as a reliable and current source of scientific news and information; besides its Internet services there are its media, the "Newsletter","Edition Wissenschaft" and "Infoline". It is not only the news item itself, but the whole topic area that is highlighted by the provision of background knowledge in order to give interested laypersons as well the possibility to get comprehensive information about the state of art in the area of EMC.

"Research and Information" – these are the two fundamental values that have guided the FGF in the past 15 years!

In this festschrift in the form of a special edition of the Newsletter we want to collect the information of the day, beginning with the contributions to the symposium up to the greeting addresses on occasion of this celebratory event to remember them.

15 years FGF –
15 years as competent contact for Radio Applications

FGF (Forschungsgemeinschaft Funk) – Research Association for Radio Applications: the name stands for internationally recognized and reliable research and risk communication in the area of radio technologies. Its reputation is proof of achievements that could hardly have been anticipated back when the FGF was being established. Network operators, service providers, manufacturers, public authorities, the scientific community, and other organizations that are members of the FGF have been key contributors in the success story. All of them have worked toward the same goal: discussion of electromagnetic fields and their biological effects on humans and the environment. Since its founding in 1992, the FGF has provided financing in the amount of 10 million Euros to support research activities.

The FGF is respected throughout the world above all for its research and communication strategy. Its thematic focuses are broadly diversified. Individual projects are selected in line with the research goals of international groups of experts and, as a rule, awarded to scientific institutions. The projects must meet the standards demanded by the World Health Organization. Among other things, they must be appropriately documented and therefore also reproducible. The FGF collaborates closely with the WHO. Results are made accessible to the specialized public in channels such as peer reviewed journals, and they are attractively and understandably prepared for the general public through various activities including workshops and information events. Several times a year the FGF's Newsletter publishes additional information on topics related to all aspects of electromagnetic environmental compatibility. Furthermore, the FGF supports the development of a scientific data base that is generally available and may be accessed at http://www.femu.de.

The FGF has thus established itself as a contact partner for numerous national and international bodies and, with its expertise and range of tasks, it is the only organization of its kind in Europe. It has convincingly shown that, according to all scientific findings, no negative effects on humans and the environment are to be expected from electromagnetic fields at frequencies below the valid threshold values. At the national level, the FGF has, among other things, helped to calm the originally very emotionally conducted discussion of the dangers of electromagnetic fields.

It might then be fair to ask, „mission accomplished?" "Yes," if the question relates to our facilitation of significantly more objective communications among decision makers and the public at large. But "no," in terms of new radio technologies, whose potential impacts have to be identified anew. Nor will the political and scientific communities ultimately be able to escape from the virtually irresolvable psychological problem of many individuals who perceive a negative influence from the mere presence of radio masts.

The FGF will have to take account of this new set of problems by, for example, placing greater emphasis on providing more information and communication and less on "research for the sake of research." I wish the Research Association for Radio Applications – also on behalf of Federal Minister Michael Glos – good fortune in meeting these challenges, and I hope that the organization will continue to serve as a competent contact partner for issues involving electromagnetic environmental compatibility.

Gerold Reichle
Director General for
Communication and Postal
Policy German Ministry
of Economics

15 years of mobile phones – 15 years of research efforts

Dear ladies and gentlemen,

when I was elected to the Board of Directors of the FGF two and a half years ago, I felt it was more than remarkable that at the beginning of the mobile phone era in Germany the promotion of an engaged and sustainable research were launched.

Today I'm very delighted being in the position to celebrate the 15th anniversary of the Forschungsgemeinschaft Funk with you, after we celebrated the 15th anniversary of mobile phones this summer.

Certainly, the change of mobile phones from the models of the year 1992 to today's devices with their huge spectrum of features got more attention than the research into possible biological effects of radio fields and the changes in this field.

I think, however, that the changes in the field of research – and the deliverables of the Forschungsgemeinschaft Funk as well – are not less significant and spectacular.

In 1992 the situation was different:

- there was no flow of information to the public
- a number of unresolved scientific questions and
- exposure systems enabling interexperimental comparison were in their beginnings.

Regarding these questions the Forschungsgemeinschaft Funk was and still is an important pioneer. In 2006 nearly 100,000 visitors of the FGF internet services were counted in average per month.

The signal generator from the first UMTS project of the FGF became the de facto standard, which is used in nearly all UMTS projects of the German Mobile Telecommunication Research Programme.

The FGF can be proud having promoted the first multi-generation study on UMTS signals with Dr. Buschmann's project at the Fraunhofer Institute in Hannover, at a time, when demands for projects on long-term effects were rapidly growing.

The list could be extended and, hopefully, this celebration will give us the opportunity to do so.

At this point let me express my heartfelt thanks to Dr. Friedrich, his team at the Administrative Office and especially the colleagues of the Working Groups "Public Relations" and "Research" on behalf of the Board of Directors.

Without their dedication and commitment the Forschungsgemeinschaft Funk and the research promoted by this association would not have this high level of reputation as it has today.

But I wish to have a look at another aspect of this change as well, which is not wholly positive from the perspective of the FGF.

What does this mean:

The large research projects are launched at the end of the nineties with the expansion of UMTS networks on a European and National level resulted for the FGF in becoming from one of the bigger research promotors to a less bigger one from a financial point of view.

Of course the relevance of these programmes for answering the open scientific questions within the EMF Project of the World Health Organisation cannot be denied and must be welcomed also regarding the scope of the FGF's activities. But for the FGF this also meant that some long-standing members have terminated their membership.

Sure, in some cases the reason may have been that the production of mobile phone or radio devices was stopped. But also in considering the large international EMF research programmes they did not find it necessary to be a member of the FGF any longer.

I do not share these thoughts.

In my view, the FGF is still needed in the future, because we have to answer the questions, like

- What will happen regarding public perception after the results from the research programmes have been published?
- Who will evaluate and explain the results and make them available to interested circles in Germany?

- Who will maintain consistency and sustainability after the large programmes are finished?

I see an important mission of the FGF here. But change is required as well.

This change and the corresponding repositioning of the Forschungsgemeinschaft Funk has already started.

In recent years, the Forschungsgemeinschaft Funk did not only initiate and commission research projects, but also has become an important platform for dialog of scientists and stakeholders in organising adequate workshops.

The workshops e.g. on the "Blood-Brain Barrier", "Genotoxicity" or "Sleep Disturbances" addressed important questions and issues. Hence, the FGF was positioned as a partner in cooperation with the European COST initiative and the World Health Organisation. This is also an important contribution made for the networking of German and international EMF research.

In my view, future research promotion of the FGF will have four important foundations:

1. Providing transparent information on EMF research to the members of the FGF and the interested public in Germany

Examples for this are the internet and intranet services of the FGF, its publications and also the supporting of the EMF portal at Aachen University, reviewed by the WHO, which was launched as a project of the FGF and has since been supported by it, together with many others.

2. Platform of dialog with important stakeholders

My colleagues and collaborators, but also researchers repeatedly confirm that the project presentation and workshops of the FGF enable just the contact and conversations needed to obtain information on emerging technologies at an early stage or to facilitate the critical constructive discussion of different research approaches.

3. Workshops on scientific opinion formation

This work was already successfully triggered by the FGF in organizing the workshops mentioned above. And it will continue to play an important role regarding the discussion of results from ongoing research programmes. In my view, it is important that such workshops take place just here in Germany, in order to get German scientists more strongly involved in the debate on EMF risks.

4. Promotion of original research

Last, but not least the promotion of experimental and epidemiological research projects as a FGF core task, of course. Only who actively promotes research, maintains the competence to assess current research.

In conclusion, let me stress the importance of these four future core tasks of the FGF. I am convinced that the FGF with this positioning will make an important contribution to an objective and responsible handling of radio technologies for the members and the interested stakeholders.

Since January 2007, Karl-Wilhelm Siebert, Director Regional Network & Operations Branch West, Vodafone D2 GmbH, is the Chairman of the Board of Directors of the FGF.

ICNIRP-Standards: Rational bases and future developments

Paolo Vecchia

The International Commission on Non Ionizing Radiation Protection (ICNIRP) was created in 1992 as an independent expert group responsible for providing advice to national governments and international organizations on possible health effects of non ionizing radiation (NIR) – including electromagnetic fields – and the ways to protect against such effects. ICNIRP took over activities and responsibilities of an International Non Ionizing Radiation Committee (INIRC) that operated from 1977 to 1992 inside the International Radiation Protection Association (IRPA).

During thirty years, guidance provided first by IRPA/INIRC and later by ICNIRP has evolved from simple recommendations for limiting exposure to specific sources and in restricted frequency ranges to a complex and comprehensive protection system. The general approach to NIR protection and the basic criteria for the development of ICNIRP recommendations are detailed in an *ad hoc* scientific paper [1].

ICNIRP issued in 1998 a guideline document on the exposure of workers and the general public to electromagnetic fields in the frequency range from 0 Hz to 300 GHz [2]. Such document superseded previous guidelines that had been published by IRPA/INIRC, separately for radiofrequency electromagnetic fields (100 kHz – 300 GHz) [3] and for power frequency (50/60 Hz) electric and magnetic fields [4]. Although the new standards were based on a much wider scientific database, the very rationale and the exposure restrictions did not change substantially, indicating

that the research in the area had already reached a high level of maturity, both in the identification of biological and health effects, and in the understanding of underlying interaction mechanisms.

The long time elapsed since the issue of last guidelines, and the accumulation of new data, require however that the existing recommendations be reviewed and updated, and ICNIRP has already started the revision process. Considering the different advancement of scientific research and risk assessment, the Commission has decided to split the new guidelines in two documents, covering low frequency (0 Hz – 100 kHz) and high frequency (100 kHz – 300 GHz) fields, respectively. The basic criteria and the steps of the process will be the same in the two cases, and are briefly discussed in the following sections.

Steps in the development of ICNIRP standards

A basic feature of ICNIRP guidelines – and of similar standards developed by a number of international organizations and national governments – is that they are firmly based on established science, and aim at protecting against all, and only, adverse effects that have been clearly indicated by high-quality research.

The starting point for the development of guidelines is therefore an in-depth analysis of the literature, and a scientific assessment of health risks. ICNIRP performs this task in cooperation with other international bodies, namely the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC).

As a first step, ICNIRP carries out a comprehensive review of the scientific literature concerning exposure assessment and dosimetry, biological effects, epidemiology, and interaction mechanisms. On its side, IARC evaluates those studies that specifically address a possible role of EMF in the development of cancer and, when appropriate, classifies the different types of EMF according to their carcinogenic power. Finally, WHO uses input from ICNIRP and IARC to perform a global evaluation of all possible health risks of EMF exposure.

The deliverables of such risk assessment procedure are in the form of ICNIRP reports (so-called "blue books"), IARC monographs, and WHO's Environmental Health Criteria (EHC). They constitute the scientific basis for ICNIRP to revise and update its guidelines.

The process described above has been completed for low frequency fields, and the corresponding monographs have been published [5,6,7]. Based on these documents, ICNIRP has recently started the revision of its guidelines for the frequency range between 0 Hz and 100 kHz.

The corresponding process for radiofrequency (RF) electromagnetic fields has been intentionally delayed, due to the present, rapid evolution of scientific knowledge. A very intensive research effort has in fact been produced in the last years, focusing in particular on RF fields generated by mobile telecommunication systems. Within the 5th Framework Program of Research funded by the European Union, several large projects have been launched involving international collaboration between different research units; while most of the experimental work has been completed, some data are still being analysed or waiting for publication. Of special interest in this context is Interphone, an epidemiological case-control study on tumours in the head and neck in relation to the use of mobile phones. With research units from 13 different countries and several thousands of cases collected, Interphone represents the largest study of this kind ever performed.

Scientific bases of guidelines for radiofrequency fields

As already mentioned, ICNIRP guidelines are only based on science, and on effects that have been scientifically *established*. An effect is considered established when it is indicated by high-quality studies, the findings are independently reproduced in replication studies, and the evidence is consistent across different research areas (e.g. epidemiological findings on humans are coherent with laboratory studies on animals, results of *in vivo* studies are supported by those *in vitro*, etc.).

At the time the first RF guidelines were issued by IRPA/INIRC, the only established health effects of RF fields were acute in nature, and were associated to the absorption of electromagnetic energy by body tissues, with an associated increase of body temperature. These "thermal" effects were clearly established, physically and biologically understood, and well characterized in terms of exposure-effect relationships. There was in fact clear evidence that such effects only occur above a threshold depending on a number of exposure characteristics that had also been identified.

Though a number of biological responses to low-level exposures have been indicated by laboratory studies, no biological effect potentially relevant for human health was identified below thermal thresholds. Based on the general approach of IRPA/INIRC, the scientific rationale of the guidelines was therefore based on thermal effects only.

The basic restrictions and reference levels recommended in 1988 were essentially confirmed in 1998. The large number of studies carried out in the time period elapsed between the two standards had in fact provided further support to the original conclusions and the scientific rationale remained unchanged, though based on more data and refined analyses.

While confirming that only acute effects were scientifically established, in the rationale of the revised guidelines some discussion is devoted to the issue of possible long-term risks of exposure, that has raised big controversies and public debates in recent years.

Consideration of long-term effects

A variety of studies, both biological and epidemiological, have been carried out in recent years to test the hypothesis of long-term effects – including cancer – of chronic exposures to field levels below the ICNIRP guidelines.

The issue was already considered by IRPA/INIRC in its 1988 guidelines, with a short mention in the last paragraph of the rationale for exposure limits: *"The Committee considered the recent data linking electric and magnetic field exposure to increased cancer risk or congenital anomalies [...]. Available data are inconclusive and cannot be used for establishing exposure limits".*

In the two last decades, however, the possibility of long-term effects has become a central issue both from the scientific point of view and for the development of health policies. ICNIRP has paid continuous attention to the advancement of research, through its Standing Committees on Epidemiology (SC I) and on Biology (SC II). In the 1998 guidelines a full section of the chapter on the biological basis for limiting RF exposure is dedicated to a critical review of cancer studies (epidemiological), and a relevant part of

the discussion on cellular and animal studies deals with biological endpoints that may be relevant for the promotion of tumours or other degenerative diseases. The conclusion essentially confirms the position of IRPA/INIRC, but on the basis of a much more consistent literature: *"Although there are deficiencies in the epidemiological work, such as poor exposure assessment, the studies have yielded no convincing evidence that typical exposure levels lead to adverse reproductive outcomes or an increased cancer risk in exposed individuals. This is consistent with the results of laboratory research on cellular and animal models, which have demonstrated neither teratogenic nor carcinogenic effects of high-frequency EMF".*

ICNIRP continuously monitors the advancement of research and checks the adequateness of its recommendations to most recent findings. In 2004, a review paper was published by ICNIRP's Standing Committee on Epidemiology [8]. The main conclusion was that *"Results of epidemiologic studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect. On the other hand, these studies have too many deficiencies to rule out an association".* At the same time, biological studies on animal and cellular models have provided no support to the hypothesis of a role of RF electromagnetic fields in the development of cancer and other long-term pathologies.

The most recent results, both epidemiological and biological, did not modify the above evaluations, and there is therefore no reason for ICNIRP to change its judgement on the impossibility to define any sound exposure limit to prevent long-term effects.

Science-based standards and precautionary policies

While only acute effects have been scientifically established, the possibility of long-term adverse consequences of chronic exposure below the thresholds for acute effects cannot be dismissed in principle, since science cannot prove the negative.

In order to prevent or reduce these risks, though hypothetical, some national governments or local authorities have adopted measures that replace or complement science-based exposure limits. In general, the *precautionary principle* is invoked to this purpose. In spite of its popularity, the principle is not well defined, and is variously interpreted. In addition, a possible conflict between science and the principle has been outlined [9]. An important clarification was provided by the European Commission (EC) [10]; it stressed that a basic condition for the principle to be invoked is that a potentially serious health hazard had been identified and scientifically evaluated. Therefore, science should be the fundamental basis – though not the unique one – for the adoption of precautionary policies.

Other criteria are indicated by EC for the correct application of the principle. The selected measures should be *inter alia*: tailored to the chosen level of protection, non-discriminatory, comparable to measures taken in equivalent areas, based on a cost/benefit analysis, and provisional.

Examining in this respect the case of EMF, WHO considers that *"[...] a cautionary policy for EMF should be adopted only with great care and deliberation. The requirements for such a policy as outlined by the European Commission do not appear to be met in the case of either power or radio frequency EMF"* [11].

The inapplicability of the precautionary principle does not necessarily mean disregarding any precaution. On the contrary, WHO recommends that in the presence of scientific incertitude (that is unavoidable in principle) any political decision be taken in the context of a *precautionary framework*, where besides scientific evidence of risk also social and economic factors are taken into account, including public sensitivities.

As already noted, socioeconomic considerations fall outside the remit of ICNIRP, whose role in the implementation of precautionary measures is limited to a scientific assessment of the plausibility of a health effects ant to an esteem of the potential health impact, where possible.

Anyway, both WHO and ICNIRP stress the importance that precautionary measures, and the way by which they are implemented, be such as not to undermine science-based exposure limits.

Future developments of the ICNIRP guidelines

The development of safety guidelines is a dynamic process that evolves with the progress of knowledge. ICNIRP continuously checks the validity of its recommendations by monitoring both the advancement of research on biological and health effects of electromagnetic fields, and the development of emerging technologies that may involve the introduction of new sources and new modalities of exposure. While there seems not to be an urgent need to change basic restrictions and reference levels, an update of the scientific rationale that includes the most recent research findings could be appropriate.

A comprehensive review of RF guidelines would be illogical and unwise at this moment. What national health authorities and the public expect is in fact not the confirmation of restrictions based on acute effects (that appear quite consolidated), but rather a position of ICNIRP on long-term risks. Whichever position is premature, however, before the publication of final results of the Interphone study and of some important biological research that is being finalized right now. Only after completion of these studies, IARC will convene an expert group for the classification of radiofrequency fields with respect to human carcinogenicity. Further steps of risk assessment by WHO and revision of guidelines by ICNIRP will follow in sequence, and the whole process will necessarily take some years.

References

- *1. ICNIRP (2003). Approach to Protection Against Non-Ionizing Radiation.* Health Phys *82:540-548. Available from: http://www.icnirp.org/documents/philosophy.pdf*
- *2. ICNIRP (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz).* Health Phys *74:494-522, 1998. Available from: http://www.icnirp.org/documents/emfgdl.pdf*
- *3. IRPA/INIRC (1990). Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields.* Health Phys *58:113-122.*
- *4. IRPA/INIRC (1988). Guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range from 100 MHz to 300 GHz.* Health Phys *54:115-123.*
- *5. IARC (2002).* Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. *Monographs on the Evaluation of Carcinogenic Risk to Humans, Vol. 80. Lyon: International Agency for Research on Cancer.*
- *6. ICNIRP (2003).* Exposure to Static and Low frequency Electromagnetic Fields, Biological Effects and Health Consequences (0-100 kHz). *(R. Matthes, A.F. McKinlay, J.H. Bernhardt, P. Vecchia, B. Veyret, Eds.). Munich: International Commission on Non Ionizing Radiation Protection.*
- *7. WHO (2007).* Extremely Low Frequency Fields *(Environmental Health Criteria 238). Geneva: World Health Organization. Available from: http://www.who.int/peh-emf/publications/elf_ehc/en/index.html.*
- *8. ICNIRP Standing Committee on Epidemiology: Ahlbom A, Green A, Kheifets L, Savitz D, Swerdlow A. (2004). Epidemiology of Health Effects of Radiofrequency Exposure.* Env Health Perspect *112:1741-1754.*
- *9. Foster KR, Vecchia P, Repacholi MH. Science and the precautionary principle.* Science *288:979-981, 2000.*
- *10. European Commission.* Communication on the Precautionary Principle, 2000. *http://europa.eu.int/comm/off/com/health_consumer/precaution.htm*
- *11. WHO (2000).* Electromagnetic fields and health: Cautionary policies. *Geneva: World Health Organization. Available from: www.who.int/docstore/peh-emf/publications/facts_press/EMF-Precaution.htm*

Dr. Paolo Vecchia is the Chairman of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Director of the Department of Technology and Health at the National Institute of Health, Rome, Italy.

The FGF's contribution on biological

by Wilma Dubois

The FGF began its work in 1992, at the time when the first digital mobile communication network, the mobile communication network of the 2nd generation "GSM" (Global System for Mobile Communication) were introduced. Electromagnetic fields (EMF) had been emitted as radio waves by radio and television stations, radar systems, etc. for decades. At that time, mobile radio was used by only about 1 % of the general population of Germany. The number of research investigations published in scientific journals on the topic of mobile communication was low (1992: < 10), there was not much EMF research going on in Germany and it was restricted to technical aspects.
With the expansion of digital mobile communication networks and the related installation of transmitting masts concerns over health risks from electromagnetic fields steadily increased.

It was against this backdrop that two core tasks were presented to the FGF: on one hand the provision of objective and comprehensive information to the public regarding the state of scientific knowledge about biological effects of electromagnetic fields on humans and the environment and on the other hand, the focus of research on high-frequency fields as are used for modern radio technologies. The primary objective of the FGF's research work was to close gaps of knowledge, to strive for higher quality of research as well as insurance the quality of experimental research projects.

The four phases of research work

After taking stock of available knowledge, highlighting the context of public risk perception and searching for open questions regarding "Electromagnetic Compatibility with the Environment" (EMC), the FGF first decided to conduct own experimental biomedical studies, relying on a basis of five different levels of investigation that comprise experiments with molecules, cells, animals, humans and medical devices (e.g. cardiac pacemakers). Due to the high costs, projects in "epidemiology" were not on the agenda of the FGF.
The 15 years of the FGF's research work can be separated in four phases (1-4), according to the focus of research activity.

to the research effects of EMF

First phase: cooperation with the „Research Association Electromagnetic Compatibility of Biological Systems“ and the “Research Initiative North Rhine-Westphalia“

The first phase of research work in the time between 1993-1996 was characterized by the cooperation with the “Research Association on Electromagnetic Compatibility of Biological Systems“ in Braunschweig, directed by Prof. Dr.-Ing., Dr.-Ing E.h. Karl Brinkmann, that existed for more than 20 years, and the Research Initiative NRW on the topic of “Biological effects of electromagnetic fields“. At the end of 1993, this cooperation led to the commissioning of first experimental research projects. Four out of five levels of investigation mentioned above were considered in selection. The focus of interest were possible genotoxic and cancer promoting effects as well as

The Different Investigation Levels of Research Projects

Population – Epidemiological studies (this is not a research topic # for projects supported by the FGF)

Addresses the question as to whether or not high frequency electromagnetic fields have an effect on an entire population (how often does a certain illness occur in combination with a specific risk factor?)

The Individual – Human studies / animal studies

Does a controlled application of a specific factor (e.g. a electromagnetic field) trigger a measurable reaction in the body.

Cells and Tissue – cellular biological investigations

Can the behaviour of cells, cell associations and cell membranes be influenced by electromagnetic fields (localization of the areas effected)

Molecules – Biochemical und molecular biological investigations

Can biochemical or molecular structures be influenced by electromagnetic fields. (investigating mechanisms which cause the effect)

Medical Devices – investigations on whether or not EMF interfere with electromagnetic devices

Investigations on the effects of electromagnetic fields on electromagnetic implants, e.g. cardiac pacemakers (if applicable, effects the corresponding standard)

the effects on cell membrane function (cellular level), the effect of EMF on brain function and hence on the human central nervous system (level of humans) as well as medical devices such as cardiac pacemakers (level of medical devices). Moreover, first experiments with artificial cell membranes (bilayers) were conducted, by which in the following, an intense analysis of "EMF interaction mechanisms" (molecular level) was initiated.

In this first phase, a total of 16 research projects (plus subcontracts) were performed on the effects of high frequency fields, as are used e.g. for mobile and police radio, television transmitters and for therapeutical ends. Seven scientific (peer-reviewed, reviewed by specialists in the field) resulted in seven publications.

Second phase: new selection process

In the second phase (1996-1999) the FGF selected a new approach to the commissioning of research projects: a group of internationally acknowledged scientists is responsible for the selection in order to emphasize the neutrality and independence of the FGF. Open calls for tender with a selection of topics that followed the recommendations of the WHO Research Agenda; it was published in 1997 in the framework of the WHO EMF Project launched the year before. A total of 17 studies were started in 1997 and, in part, extended to the year 2000. Among them were also literature studies on single topics performed that completed different projects and provided information about the state of research of that time. Possible cancer promoting effects, the effects of EMF on melatonin synthesis as well as possible effects on the offspring were investigated in animal studies (level of animals). Moreover, the experiments with bilayers (molecular level) were continued in the form of calculations, analyses and experimental studies as well as experiments with the cell membrane (cellular level). Investigations of brain activity (EEGs) were continued and expanded by additional neuropsychological tests (level of humans). Another study on cardiac pacemakers concluded the observations on the level of medical devices within the research promoted by the FGF. When commercial applications of electromagnetic fields in the upper microwave range (cm/mm waves: 3 GHz to 300 GHz) emerged, a research project investigating possible effects of EMF in this frequency range was planned. 14 peer-reviewed publications were the result of this second phase of FGF research.

Third phase: UMTS

The third phase of the FGF's research work (1999-2002) stood in the sign of the new mobile communication technology UMTS, the mobile radio system of the 3rd generation, which was commercially introduced in 2004 in Germany. Already in 2001 the FGF was the first research institution in Germany to include investigations on effects of UMTS signals on biological systems in its research agenda. The studies, in part, extended over several years or are still ongoing, respectively. Experiments were conducted both on the level of animals and the level of humans. Two studies were devoted to the effects of UMTS on the central nervous system (CNS): on the cellular level the blood-brain barrier was the object of investigations, on the level of humans the visual system was more closely inspected. The level of animals was covered by a multigenerational study on possible toxicological effects of UMTS fields on the offspring of rats. For comparability with other experiments, also in the international context, the first standardized UMTS signal scheme was developed and published on the initiative of the FGF and is since applied in many, also international, projects.

Moreover, experiments on GSM signals were continued in this phase. Again the effect of EMF on the CNS was investigated and, on the other hand, a topic not yet considered in the experiments was studied: electrohypersensitivity.

In total, besides three literature studies eight experimental studies were promoted in this period. Nine peer-reviewed publications were the result so fare.

Fourth phase: science dialog

The fourth phase (from 2002) began against the backdrop of the increase in intensive research in Europe regarding mobile radio field risk assessment, advanced by large-scale research programmes as e.g.

the "German Mobile Communication Research Programme" or coordinated European programmes like "REFLEX", "Perform A" and "Perform B". In view of the steadily increasing number of scientific studies on EMF effects on biological systems, the FGF intensified its promotion of the review, analysis and discussion of available scientific literature and the experts' discussion of current research foci. An important part of this concept is the organization of expert workshops on special topics in order to promote the exchange of information between scientists, to work out the state of the art of science and to make reports available to interested persons. The cooperation with national and international organizations and bodies was intensified, e.g. for five years the FGF functioned as the Secretariat of the scientific coordination action of the EU "COST 281".

Moreover, the cooperation with the WHO's "EMF Project" as well as with the "Research Centre for Electro-magnetic Compatibility" *(femu)* of the RWTH Aachen was expanded further.

A focal point: expert workshops

A well-established element of FGF research activities are the expert workshops on current research topics, which now take place 2-3 times a year. They serve as a platform of in-depth discussion of the present state of knowledge for scientist. They are intended also to discuss their own results and, mainly, the questions that are still open in EMF research. The researchers can get an overview of the current state of knowledge by the observation of planned or ongoing projects. The objective, open character of the workshops quite often gives the possibility to establish productive contact between research groups. Here, the participation of experts (e.g. biomolecular scientists, sleep researchers or pediatricians) who are not active in the area of EMF research before, but have excellent experience in the methodology and the conclusiveness of studies done in the respective special areas is specially emphasized. The restricted number of participants (about 50) and the space given to discussion allow an in-depth investigation of topics and quite often result in consensus statements. An example for this may be the concept for a metastudy on genotoxic issues with sufficient statistical power, the idea of which was born and presented at the workshop in November 2002 in Löwenstein. This concept led to a recommendation of COST 281, which again was considered and implemented in a currently ongoing project of the German Mobile Communication Research Programme. The selection of the topics of the workshops is based on internal analyses of the present state of research and on recommendations of members of the FGF or other organizations, like for instance the WHO. Areas of research, where several studies have obtained contradictory results, as was the case e.g. regarding investigations of possible interaction mechanisms between electromagnetic fields and biological structures or investigations on the effects of high-frequency fields on the blood-brain barrier, are especially considered. A topic that is presently under discussion, namely whether children are especially sensitive to EMF exposure, was dealt with at one of the FGF's workshops.

This part of the work of the FGF has been an essential contribution to the quality improvement in the

methodology of investigations, the qualified review and evaluation of the present state of knowledge. The workshop reports are available on the Internet at http://www.fgf.de/fup/ergebnisse/erg-11work.htm.

Literature and information database

The effort to present available knowledge about EMF effects on humans and the environment in a transparent and comprehensible way was linked to the continuous support of the FGF for the literature and information database on the effects of EMF on humans and the environment (knowledge-based literature database, WBLDB). Under the direction of Prof. Silny, the information database on biological effects of low- and high-frequency electromagnetic fields was created at the Research Centre for Electro-magnetic Compatibility with the Environment *(femu)* at the Technical University of Aachen, where both experts and laypersons can get free information on the present state of knowledge through the use of scientific literature.

A compact description of the most relevant biomedical and technical aspects of each publication enables the user to get access to further information, without having to read the entire publications, which are mostly in English. The bilingual (German and English) database, financed by different institutions, was developed over many years and is today the core element of the so-called EMF portal (http://www.emf-portal.de), by which the topics and contents of special literature are made more easily comprehensible, with the help of additional information services like a "glossary", the database on "exposure sources in everyday life", the "basics" and the "forum" for users. At present, more than 10,000 publications are included, new special articles are included as they come along. All experimental studies from the biomedical area with applications of frequencies as are used in mobile communication have been evaluated regarding their biological and technical contents. Since the official opening of the EMF portal in July 2005 a steady increase in use intensity has been observed (now about 1300 visitors a day). Due to its bilingual character, the portal is also used international mainly by visitors from the USA.

Topics and the context of research work

The FGF is still conducting and accompanying experimental studies among other things to maintain its scientific competence. Within these studies, in part, novel test approaches for the investigation of the impact of EMF were developed, or, by providing initial funding, their development is made possible. So, for instance a new test approach regarding the impact of EMF on sleep quality was checked in a pilot study. The idea was that not the response of volunteers to a provocation with irradiated artificial fields, but the response to the shielding against emissions of EMF (strong attenuation of the impact made responsible by electrosensitive volunteers for their sleep disturbances) should be investigated (project EPROS: Electrosensitive Protected Sleep).

Furthermore, an ongoing animal study accounts for the urgent need for longterm studies. While many of the studies termed "longterm studies" do not exceed an experimental phase of about two years, this study is a true lifetime study; the animals are exposed, observed and examined until their natural death.

In another ongoing study whole-body dosimetry is calculated under complex field conditions against the backdrop of the steady increase in the simultaneous exposure of humans to many technical electromagnetic field applications.

A multigeneration study, considering possible fetus-damaging effects of UMTS signals etc., is not finished either.

Moreover, several literature studies, e.g. accompanying own studies and workshops of the last years (4th phase), were commissioned.

In the 15 years of the FGF's research the planning, construction and field-calculation regarding applied exposure systems were continually improved and adapted to the state of technology. Examples for this are: the development of a small TEM cell and of several hollow wave guide cells for microscopic "in vitro" tests, several radial wave guides for animal tests or tests with tissues and cells, an antenna system for the nocturnal exposure of volunteers in sleep studies investigating the CNS, as well as the design of special exposure rooms and antenna systems for other human high-frequency experiments. Moreover, the definition of a standardized GSM signal and UMTS signal ("generic test signals") for research commissioned by the FGF served to improve the qualitative standard of EMF research and the comparability of different experiments. Due to the progress of computer technology, sophisticated dosimetry calculations became possible. The quality of experiments on the „biological level" was ensured by following the standards recommended by the World Health Organization (WHO) in its commissioning. Special emphasis is put on the transparency and the critical discussion of study contents and results promoted by the FGF. This is guaranteed by a competent and continuous project accompaniment, the documentation of results in final reports, by public scientific colloquia on each experimental study, by publishing the results in peer-reviewed special journals and presenting them in a comprehensible manner in the media of the FGF (Newsletter, Edition Wissenschaft, etc.). The above-mentioned expert workshops on current research topics also contribute to this. The research results hence are always made available for scientific discussion and for general information. If possible, external experts are included in each phase of a project (definition of objectives, selection, study design, final evaluation).

Overview of single topics in research work

Looking back, there were four topics in the aforementioned four phases of FGF research activities, which were investigated in several phases from different perspectives, as well as five topics that were in the focus for a shorter time.

The following four topic were being investigated over a longer period:

- interaction mechanisms of EMF
- effects of EMF on the central nervous system
- possible cancer-promoting effects of EMF
- possible genotoxic effects of EMF

Interaction mechanisms

The results of a project with artificial membranes launched in the first years of the FGF's research work (bilayers) in the following led to intense discussion of the topic of possible interaction mechanisms between weak EMF and biological structures. The hypothesis of the study was: if there is an interaction between weak high-frequency fields of radio applications and biological structures, evidence of it should be found also in the model "artificial membranes" without these effects being overlapped by natural processes of cells and the whole organism, respectively. Hence it should be possible to identify the molecular mechanism of a potential interaction and to extrapolate it to complex biological systems. The results of this first study were supported by dosimetric analyses and calculations and followed up in a literature study, a reproduction study and an expanded study with polymer foils. A final publication was submitted to a peer-reviewed journal and shall be published in the near future. Several literature studies and FGF workshops on this topic provided the scientific background and offered the possibility to discuss this fundamental issue on the international level. The investigations of artificial membranes to date are unique in their form.

Effects of EMF on the central nervous system (CNS)

The effects of EMF on the human CNS as the most frequently investigated topic were also examined in FGF research. Seven experimental studies and six literature studies and workshops, respectively, focussed on this important topic in the 15 years of the FGF's existence. First, the brain activity in the waking state and the cognitive competence at exposure to

EMF was in the focus of interest. Later corresponding examinations were conducted during sleep – they were among the first experiments of this kind. In 2002, a series of contradictory or non-reproducible research results on possible EMF effects on the CNS were available. The FGF initiated another project investigating the cognitive performance under special consideration of the field modulation (pulsed/continuous) and the exposed brain hemisphere. The effects of UMTS fields on the human visual system and the brain blood barrier were examined in FGF studies. None of these studies observed field-specific effects on the study objects. Nearly all studies on this topic promoted by the FGF were published in peer-reviewed special journals.

Cancer-promoting effects

Overall, three experimental studies on this topic were conducted in the years 1993 to 1998. Two "in vitro" studies examined the growth behaviour of human leukemia cells, one "in vivo" study investigated possible cancer development in mice. None of the studies could give evidence of cancer promoting effects of EMF. In two other "in vivo" studies in rats the focus was also on pathological organic changes and, hence, possible cancer development as well (1996, 1999). Evidence of cancer initiation at field exposure was not found, either. For in-depth discussion of this topic an FGF expert workshop titled „Are RF fields able to raise the risk of cancer?" took place in 2004.

Genotoxicity

The genotoxicity of EMF was considered during the first phase of the FGF's research (1993-1996) as one of the first topics. On the molecular level possible genotoxic effects of mobile radio fields (GSM 900, 1800) on biological molecules (DNA and proteins), human cells as well as bacteria and viruses were examined. No clear, reproducible effects were observed. Own studies on this topic were not followed up. But the topic of genotoxicity was discussed during two workshops (2002, 2007) as well as – in a broader sense – in a literature study and two workshops on gene expression and heat shock proteins (HSP) (2003, 2004, 2005).

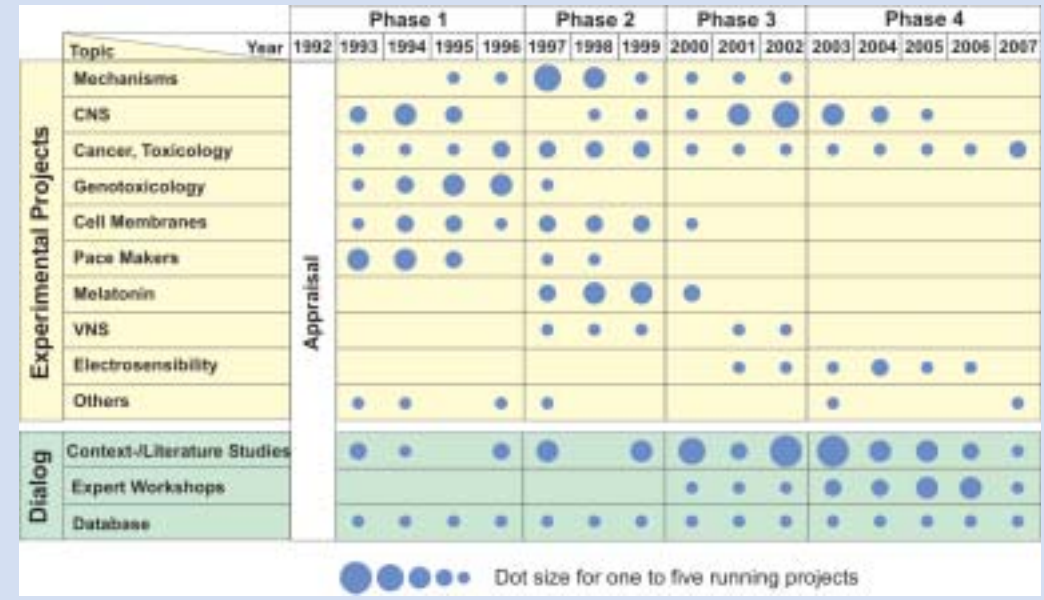
Contrary to the above-mentioned topics, the following five topics were observed over a shorter period:

- effects of EMF on cell membranes (1993-1997)
- impact of EMF on cardiac pacemakers (1993-1998)
- impact of EMF on the melatonin synthesis (1996-1999)
- effects of EMF on the autonomic nervous system (1997-2000)
- electrohypersensitivity (2001-2005)

Some of the first studies promoted by the FGF were devoted to the topic of a **possible effect of EMF on cell membranes**. This effect was examined via the measurement of ion concentrations (calcium), membrane currents and membrane potentials in cells of animals and humans. None of the studies observed field-specific effects.

On the level of medical devices calculations, measurements as well as computer simulations of interference voltages were conducted in a body model in the first five years of the FGF research programme. The question was whether there are interference effects of high frequency EMF as are emitted by mobile radio devices and television transmitters on cardiac **pacemakers**. In the 2nd phase the topic of "Effects of EMF on the **melatonin hypothesis**" was examined in form of theoretical considerations (literature study "The melatonin hypothesis") and in three subsequent experimental investigations. The research plan was to examine the melatonin hypothesis in the selected object on three different biological levels, the level of cells, organs and the living animal. Final conclusions on these experiments are being prepared for scientific publication.

Possible effects of EMF on the autonomic nervous system (ANS, the part of the nervous system controlling involuntary, often unconscious body functions, e.g. digestion, heart rate, breathing, etc.) were closely inspected over a limited time period in three subsequent projects. The ANS had already been examined in the context of military applications, e.g. radar, but not in association with cm/mm waves, which were used in emerging technical applications in the civil sector (e.g. distance radar in vehicles). By promoting corresponding projects, the FGF responded to this gap of knowledge. Effects on the human ANS at



This table is an overview of the number of ongoing projects promoted by the FGF per year and focal topic. The length of some projects – sometimes several years – is correspondingly reflected in the number of points given to each project, i.e. the points symbolize either single one-year projects or a project of several years.

exposure to cm/mm waves could not be observed.

A project just recently finished was devoted to **electrohypersensitivity**. It was the aim of this provocation study with volunteers performed under laboratory conditions to investigate electro sensitivity at exposure to simulated electromagnetic fields of a D net mobile radio base antenna. There was no statistically significant evidence that the volunteers sensed the electrical field used in the experiment under the selected laboratory conditions (completely shielded from external electrical fields).

In another study, mentioned in the paragraph on "Topics and the context of research work", the development of a novel test approach (project EPROS: Electrosensitive Protected Sleep) was promoted in a pilot study.

In view of the summary reports of different national and international research programmes (DMF, Interphone, WHO EMF-Project) that are soon to be expected, the FGF will increasingly devote resources to the review, evaluation and mediation of research results (science dialog, communication). Nevertheless it is planned at present to continue the promotion of own research (to a smaller extent) in order to maintain own scientific competence. Emerging technologies (e.g. RFID, WiMAX, etc.) may point the way.

The European Research Advisory Board (EURAB) recently recommended that there be a conclusive exchange between science and society. The FGF will continue to make a valuable contribution to this.

Dr. rer. nat. Wilma Dubois is biologist; in the FGF she is responsible for project accompaniment and research monitoring.

15 years on biomedical mobile

A story of success

by Roland Glaser

It is worthwhile to take a look back at the past 15 years of research on potential health effects of high-frequency fields in order to draw conclusions and perhaps define new tasks. However, many of the topics and hypotheses investigated over the last 15 years have been identified earlier, therefore a look at older publications is inevitable. Most problems in the meanwhile were scientifically investigated and solved as required. Yet gaps and unclarities are repeatedly pointed out, generating discussion and uncertainty in the public sphere.

Even though the research on biomedical effects of high-frequency fields has not begun with the era of mobile phones[34], the annual number of publications in international scientific journals is distinctly increasing (fig. 1). In contrast, the number of publications on effects of alternate current low-frequency fields on biological systems is decreasing after a maximum in 1998.

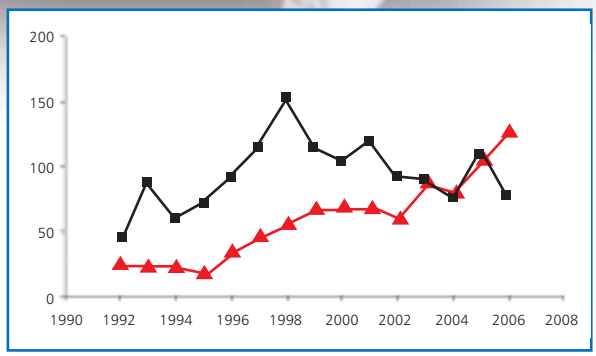


Fig. 1: Trend lines of the annual distribution of 960 publications on biological effects of EMF in the frequency range between 0.3 and 3 GHz (UHF) (red) and of 1446 investigations regarding the power frequency (50 and 60 Hz, respectively) (black) over the past 15 years.

# of research
effects of high-frequency communication fields
or an endless story?

Of course, this trend is mainly caused by the increasing relevance of the high-frequency issue as a consequence of the wide distribution of mobile phones and other forms of high-frequency data transfer. As a result, there was a corresponding reorientation of research funds.

This paper is not focused on the quantitative analysis of this situation but rather on the contents of research and the results that have become available over the past 15 years. This will be done exemplarily, related to the main trends of the development.

One specific trait of this field are the extremely high requirements to interdisciplinary competence – beginning at the proper handling of elaborate field application technology and dosimetry, knowledgeable experience in animal care and cell biology, knowledge of biomolecular aspects, and finally resulting in medical evaluation of the observed biological effects. Special knowledge is required, associated with an urgent need of interdisciplinary cooperation. Research in earlier years often suffered from the fact that biologically oriented working groups used primitive electronics, whereas groups with technical background had a naive understanding of biological concepts. Although such dubious experiments are published even to day, the faulty results of them making a huge splash, a distinct trend to high-quality multidisciplinary research has been observed over the last decades, which, increasingly, is based also on multinational cooperation.

The development of application systems and dosimetry

While there is no difference regarding biomedical analysis techniques in investigations between low-frequency and high-frequency EMF, the technical requirements are much higher regarding the RF range. Biological experiments in the GHz range require considerable technical and thus also financial expenditure, beginning with generators, via amplifiers up to defined transmission systems in a anechoic environment. It is not sufficient to place a mobile phone near a Petri dish, as, unfortunately, is done sometimes even in recent publications (e.g. 25, 79, 80, 99). Experimental data can only be taken seriously in research today, if technically accurate application conditions and a corresponding dosimetry are used.

There are several cases in the reporting period, where there was no evidence anymore for originally found biological effects in repeat studies after correction of application conditions. As an example, we should mention the investigations on the nematode *Caenor-*

habditis elegans. There was no evidence anymore of the expression of a heat shock protein (Hsp16) (termed "non-thermal") at SARs of 1 mW/kg[17] after correction of the application system[18]. The – correctly measured – effect was caused by heating of the extremely temperature-sensitive animals. Also the spectacular findings regarding tumor promotion at exposure to 900-MHz fields in transgenic mice[84] had to be revised after the method of field application had been made more precise[93].

In both cases, the working groups themselves revised their results. Unfortunately, these are exceptions. Mostly the results of one laboratory are denied by repeat studies of others. This frequently is interpreted as a case of conflicting opinions by outsiders. At best, a philosophical thesis can be "refuted". An experimental finding can raise doubts, if it is not reproducible, but it cannot be "refuted". It is only the evidence of methodological errors, as far as they can be recognized at all from the publication of results, that can explain the fruitless attempts to replicate an experimental finding and enhance the probability that the result is wrong. In spite of that – and unfortunately, there are many examples for that – faulty measurements frequently are used argumentatively by some campaigners. The neglect of methodological diligence still is a major source of false conclusions[46]. Unfounded concerns of citizens are repeatedly caused this way, intensified by corresponding press campaigns.

Accurate knowledge through the use of modern biomedical analysis techniques

Of course there is clear methodological progress not only regarding RF technology, but also concerning methods of biomedical analysis. While the former has to be seen mainly as the use of already existing technical knowledge for the development of applicators and dosimetric methods, bioelectromagnetic research directly profits from the rapid development of biomedical techniques in general.

Examples are the development of HTS technologies (High Throughput Screening Technologies), a group of methods in biomolecular analysis allowing to get a huge number of biomolecular data from smallest samples[62] in very short time. However, great diligence regarding the statistical verification of results is required here as well. Premature conclusions regarding the possible expression of stress proteins and their potential cancer risk[61] had to be withdrawn later[45, 48, 94]. Only precise knowledge about the physiological variability of these complex parameters, associated with the conduct of positive controls allow to correctly interpret possible alterations in the exposed system. The fast determination of a large amount of data alone is not sufficient.

In this context also the discussion about the experiments should be mentioned, where it was concluded that DNA damages in human fibroblasts[20] were caused by RF fields near the upper limit. The authors of this paper referred to results obtained by the so-called comet assay, an electrophoretic test routinely used for the detection of DNA strand breaks. This test, especially if the evaluation is made manually and not automatically as in these experiments, is not per se sufficient for drawing far-reaching conclusions. It also indicates aberrations in the regular cell cycle[95]. Conclusions could only be legitimized by evidence of other consequences of this process. Attempts to reproduce the results by means of an improved technique had no result[89].

The investigation of possible effects of high-frequency electromagnetic fields on the cognitive performance of humans, their reaction time, but also their sleep behavior, profited a lot from the general development of neurophysiology and its methods. On one hand, this concerns EEG measurements, but also the possibility to make blood flow alterations visible by means of Positron Resonance Tomography (PET)[51, 52]. Unfortunately, by technical reason, many of those methods can not be used during RF exposure[14]. Surprisingly, many of such investigations show unreproducible effects. In some cases, the research groups failed to reproduce their own results (e.g. Röschke[85] versus Wagner[97]; Eulitz[24, 39] versus Hamblin[40]). In contrast to the examples above mentioned however, in most cases this does not seem to be a result of technical lacks or of lacking diligence of the

experimenters, but are caused by the system behavior itself. The conclusion was that not the exposure of a mobile phone base station near by, but sometimes the fields of a mobile phone at the ear can affect the brain. This influence however, obviously depends on the physiological state of the volunteer and keeps within neurophysiological day-to-day variations. Initial allegations that such measurements would show adverse health effects[56] are untenable, though. Nevertheless the mechanisms leading to such effects should be checked. Krause et al.[58] assume that responses to a slight cortical heating were behind this effect, indicated also by local changes in blood flow, as measured by PET[51]. Obviously, the sensitivity of the system of physiological thermoreception is still underestimated[33].

The road of epidemiological research

There has been a distinct increase in the number of epidemiological studies on possible effects of mobile radio fields over the last years, which, of course, is also due to the rapidly increasing use of corresponding devices. At the same time, there is also a clear trend to concretize results and eliminate wrong decisions.

Epidemiological studies on possible health consequences of high-frequency field exposure began by observation of occupationally exposed persons, like workers for broadcasting stations, radar and flight staff, especially in the military sector. So the study of Szmigielski[92] on alleged cancer cases in the Polish military due to field exposure, which was discussed very intensely and controversially. Surveys on occupational exposure to RF fields however did not show a clear association, mainly due to the lacking dosimetry as well as the different and, in part, very strong confounders, i.e. the influence of other specific occupational agents[11, 22, 23, 55].

It was only in the nineties that studies on the possible consequences of high-frequency exposure of the population were published. For example, a possible association between child leukemia and the vicinity of radio and television towers was investigated[21, 49, 69, 70]. Rothman et al.[86] for the first time stressed the need for epidemiological investigations of a possible link between RF exposure and brain tumors, at the same time pointing out the methodological problems of this endeavor.

It was only at the end of the nineties that epidemiological research directly focused on potential effects of mobile phones. The first case-control study on a possible association with the occurrence of brain tumors probably is that of Hardell et al.[43] from 1999. In the subsequent years some other case-control studies were published, but they did not allow to draw distinct conclusions[42, 43, 54, 72, 74, 75, 100]. Moreover there were publications addressing the lack of physical well-being and other general symptoms related to living in the vicinity of mobile phone base stations[7, 76] . These studies, however, often had serious methodological flaws.

A comprehensive summary of the situation was compiled by five members of the ICNIRP Standing Committee on Epidemiology[5]. They concluded that, until 2004, epidemiological findings did not provide conclusive and convincing evidence for a causal association between exposure to high-frequency fields and any serious health damage. At the same time, possible sources of error were pointed out both regarding statistics and dosimetry. Repeatedly, there is the problem of small numbers. If only about an average of 10-15 persons out of 100,000 per year get a brain tumor, this, naturally, is not sufficient for a statistically verified survey. Another problem are the so-called “confounders“, the wealth of mostly not detected and often not detectable causes of health disturbances our modern environment is known for.

All this critique has led to a clear improvement of new epidemiological surveys, partially using the data of cancer registries[13, 59, 67, 68]. The investigations of recent years are remarkable insofar as the international cooperation led to an increase in case numbers. An example is the INTERPHONE study involving 13 countries.

Though none of the studies so far has been able to give evidence of an influence of mobile communication base stations or mobile phones on well-being or health, nearly all of these publications end by stating

that "further investigations are necessary". This may be due to the principal uncertainty of all findings, but also the concerns still existing over longterm effects, although we are better able today to identify faults and give recommendations on the type of research to be done[77, 87, 96].

Models and hypotheses on possible biophysical interaction mechanisms of high-frequency electromagnetic fields

Others already reported in depth on primary processes of high-frequency electromagnetic field effects[34]. Here, the developments of the last two decades shall be outlined and tendencies shall be made visible.

"*Hypotheses non fingo*" – (I don't invent hypotheses) Newton said, thereby pointing out the relation between experiment and theory. In EMF research, this relation is obvious: Alleged field effects repeatedly encouraged biophysicians to think about mechanisms. On the other hand, new experiments were stimulated by theoretical models. This interaction between theory and experiment results either in a spiral, asymptotically approaching the point of reality or, if objective reality does not support the theory, an endless cycle, which gradually peters out.

In the case of dielectrophoresis and electrorotation there was a spiral of success: experiment and theory led to insights that have their firm place today in biotechnology[31, 35]. These two non-thermal processes of polarization caused by high-frequency fields however require field strengths, several magnitudes above the legally prescribed limits, and therefore are without relevance for the topic of this contribution. Unfortunately, the research on lower-intensity RF fields points in the other direction at present. This may be illustrated by two examples.

The first example is connected with the "cyclotron resonance" hypothesis of A. R. Liboff, first referring to the interaction of the static magnetic field and low-frequency EMF[63], later also to low-frequency modulated RF fields. The experiments of the laboratory of Ross Adey, due to which high-frequency fields (147 MHz) affected the calcium metabolism of the brain, if they were modulated with 16 Hz[8, 10], were especially spectacular. Already in 1982 however, Merritt and Shelton[71] had denied the findings of this group as being methodologically flawed and unreproducible. The impact of modulated high-frequency fields on the calcium signaling pathway in lymphocytes postulated by Bawin and Blackman could not be reproduced[15]. The hypothesis in the meantime was shown to be unrealistic, not only in experiment, but also physically[1]. Independent of this, it became clear that low-frequency cannot be the result of a demodulation of high-frequency fields by the biological system[28]. So this approach, promoted by many publications, petered out. The Bawin publication is still sometimes cited uncritically by certain outsider groups, if them seems useful.

The second example relates to the theory of coherent excitation of H. Fröhlich, to whom a special symposium was devoted in 1982 in Bad Neuenahr.[30] This theory and their predicted sharp resonance windows in the GHz range could neither be verified in experiment nor theoretically[36, 37], despite initial experimental evidence[38].

Related to these concepts are also the tests of T. Litovitz, who postulated a „coherence time", a short time that was needed to adapt the low-frequency coherence at HF-modulations in the biological system[66]. He still insisted on his concept of the impact of low-frequency window effects[73, 81] on ornithine decarboxylase (ODC), even after all attempts of other laboratories to reproduce this had failed [e.g.[6]] (especially on this controversy see[32, 65]).

Decisive progress made in the past decade is reflected in the statement – which was experimentally and theoretically confirmed – that there can be no resonant energy accumulation of high-frequency oscillations due to the strong viscosity reducing effects in the watery milieu[2, 3, 12, 26, 82, 83]. Thus the arguments for the existence of sharp frequency windows of high-frequency effects do not apply anymore either.

Neither the originally suspected induction of calcium signals nor the ODC findings[19, 45, 50] , nor the initially alleged changes in the melatonin metabolism[44, 90, 101] could be confirmed. Many of these findings were based on the methods of fluorescent microscopy. It is often

overlooked that the cells are sometimes exposed to UV radiation here, producing clearer effects than high-frequency fields[53].

In recent years, an influence of high-frequency EMF on the complicated system of the elimination of reactive oxygen species (ROS) of the cellular metabolism, suspected already in 1985[64], has been controversially discussed again[25, 29, 57, 60, 78, 88, 102]. There is no plausible biophysical mechanism supporting this hypothesis. The future will show whether the measurements can be verified or whether those will be right who see the biological variability of this system and the uncertainty of the analysis technique as the cause of to-date findings.

Summing up this paragraph, the conclusion must be that the 15 years of this reporting period were a time of clearing up unrealistic hypotheses. Recalling Newton's "*Hypotheses non fingo*", the question is allowed: What undeniable experimental effects do still require a biophysical explanation today?

"Non-thermal" or "subtle thermal" effects?

When looking at the neurological measurements initially listed, including their variability, as well as the repeatedly published results on the occurrence of heat shock proteins[16, 91], one comes back to thermal effects of high-frequency fields, even if they are not always measurable as a temperature increase. It seems very clear regarding heat shock proteins, as many recent findings show, that this cellular response in fact can be expected only when thermal stress occurs[47, 88, 98].

The term „non-thermal effect" has a populist undertone, as it suggests that there were secretive, still undiscovered adverse health effects of electromagnetic fields, not having been considered in the setting of limits. Laypersons can be easily convinced that electrical oscillations may attack all kinds of charges, thereby causing unimaginable damage in the biological system. But the problem are not these effects per se, which undeniably exist, but rather the dosimetry and the question whether these oscillations disappear to the noise and unspecifically dissipate to heat, i.e. eventually are "thermal", or whether these smallest amounts of energy could have specific biological effects before their dissipation.

This question is as old as the research on the impact of electromagnetic fields itself, going back to the end of the 19th century[34]. The past years have greatly contributed to clarification through scientific publications and, especially, through discussion during special conferences.

Initially we reported that some "non-thermal" effects disappear after correction of the application system, because they were just the results of uncontrolled heating. But even when neglecting the results of publications providing evidence of heating effects or at least corresponding suspicions, a number of findings remain which are not as easily explained by measurable heating. Progress made in the field of thermosensitive ion channels and so-called "riboswitches" however has shown in the past decade that, in many cells, these molecular thermometers respond so sensitively in certain temperature ranges, possibly releasing biochemical signal chains, that macroscopically changes in temperature are not measurable[27, 33]. The result of such responses can be both special protein expressions, as well as local changes in blood flow, which could lead to measurable alterations in the EEG. As these responses however are also dependent of different other physiological parameters, the difficulty to reproduce these neurological effects becomes clear.

Hence "non-thermal" effects really are to be termed „subtle thermal", i.e. minimal thermal day-to-day effects. They even occur when a man is sweating on a summer day, enjoying the relaxing warm water of a shower, or his thermoregulation is otherwise activated. Of course, the biophysicist is interested in each effect of high-frequency fields on the biological system for which there is clear evidence, the radiation protection scientist on his part must notice only influences which are health-relevant. The statement of Bernhardt published already in 1999 was corroborated[9]: "A possible pathological relevance of to-date available reports on so-called non-thermal effects is purely speculative at present."

Conclusions

It seems obvious to come to the following statement: "The problem is solved. Science has proved that there are no adverse health effects of mobile communication fields within legal limits." – Unfortunately, this is true only to a certain extent: science cannot prove the non-existence of a process or phenomenon. So, the conclusion would have to be: "Last decade's research, could clear up many errors regarding effects of high-frequency fields, and despite global efforts to date no reproducible evidence could be found for a health risk from these fields within valid limits."

As EMF is no agent which concerns only a minor percentage of the population, but each citizen of the civilized world is exposed to nowadays to a different degree qualitatively and quantitatively, we cannot be content with this conclusion.

The following activities in this field seem of future relevance to the author:

- The technical application of high-frequency fields is developing rapidly, thus qualitatively und quantitatively increasing the general exposure. Although narrow window effects for special frequencies and intensities of high-frequency fields could not be found until now, certainly different interaction mechanisms can be expected for the broad frequency range of 0.1 to 10 GHz at greater intensities. This results in the obligation to reassess all technological innovations regarding health consequences of applied intensities, frequencies and modulations and, possibly, initiate new research projects in order to exclude potential health-relevant effects.
- The quantitative increase in the number of scientific publications shown in fig. 1 requires greater attention. As repeatedly experiments are published, which were performed without reliable dosimetry, double-blind evaluations and positive control, i.e. which are of lacking quality regarding modern technology and therefore are often faulty, attentive quality control is required. Unfortunately, there are many examples for results of superficial experiments or flawed performance of experiments that, accentuated by the press, led to spectacular reactions in the public. Research projects worth millions were needed, eventually failing to disqualify these results, even if they were not confirmed and sources of error were pointed out. Permanent control and instruction are needed to prevent this. Diligent observation of research activities and a well-coordinated international cooperation are a means to this end.
- It is an important and continuing task to counter unfounded concerns of citizens over possible dangers of high-frequency fields by objective information. In this respect it is even important to check the above-mentioned effects, which really are within day-to-day alterations without any health-relevance. Only by knowing the mechanism of such day-to-day effects a scientific extrapolation and assessment of exposures in general can be done.

References

(Detailed Citations: online version of the article)

1. Adair, R. K. Bioelectromagnetics 19 (98) 181.
2. Adair, R. K. Biophys. J. 82 (2002) 1147.
3. Adair, R. K. Bioelectromagnetics 24 (2003) 440.
4. Adair, R. K. Bioelectromagnetics 24 (2003) 444.
5. Ahlbom, A., Green, A.et al. Environ. Health Persp . 112 (2004) 1741.
6. Azadniv, M., Klinge, C. M.et al. Biochem. Biophys. Res. Commun. 214 (95) 627.
7. Balmori, A. Electromagnetic Biology and Medicine 24 (2005) 109.
8. Bawin, S. M., Adey, W. R.et al. Proc. Natl. Acad. Sci. USA 75 (78) 6314.
9. Bernhardt, J. H. Deutsches Ärzteblatt 96 (99) 845.
10. Blackman, C. F., Benane, S. G.et al. Bioelectromagnetics 1 (80) 35.
11. Blettner, M., Schlehofer, B. Med. Klin. 94 (99) 150.
12. Challis, L. J. Bioelectromagnetics Supplement 26 (2005) S98 - S106.
13. Christensen, H. C., Schüz, J.et al. Am. J. Epidem. 159 (2004) 277.
14. Cook, C. M., Saucier, D. M.et al. Bioelectromagnetics 27 (2006) 613.
15. Cranfield, C. G., Wood, A. W.et al. Intern. J. Radiation Biology 77 (2001) 1207.
16. Czyz, J., Guan, Ket al. Bioelectromagnetics 25 (2004) 296.
17. de Pomerai, D., C. Daniellset al. Nature 405 (2000) 417.
18. de Pomerai, D. I., Smith, B.et al. FEBS Letters 543 (2003) 93.
19. Desta, A. B., Owen, R. D.et al. Radiat. Res. 160 (2003) 488.
20. Diem, E., Schwarz, C.et al. Mutat. Res. – Gen. Toxicol. Environ. Mutag. 583 (2005) 178.
21. Dolk, H., Elliott, P.et al. Am. J. Epidemiol. 145 (97) 10.
22. Elwood, J. M. Environ. Health Persp. 107 (99) 155.

23. Elwood, J. M. Bioelectromagnetics Suppl. 6 (2003) S63-S73.
24. Eulitz, C., Ullsperger, P.et al. Neuroreport 9 (98) 3229.
25. Ferreira, A. R., Bonatto, F.et al. Bioelectromagnetics 27 (2006) 487.
26. Foster, K. R., Baish, J. W. J. Biol. Phys. 26 (2000) 255.
27. Foster, K. R., Glaser, R. Health Physics 92 (2007) 609.
28. Foster, K. R., Repacholi, M. H. Radiat. Res. 162 (2004) 219.
29. Friedman, J., Kraus, S.et al. Biochem. J. Published on 25 Apr 2007 as manuscript BJ20061653 (2007)
30. Fröhlich, H., Kremer, F. eds. - Springer Verlag, Berlin (83)
31. Fuhr, G., Hagedorn, R. In: Lynch, P. T., M. R. Davey (eds.): Chapman & Hall, New York (96) 38.
32. Glaser, R. Bioelectrochem. Bioenerg. 46 (1998) 301.
33. Glaser, R. Edition Wissenschaft 21 (2005) 3.
34. Glaser, R. News Letter FGF (2006) 10.
35. Glaser, R., Fuhr, G. In: M. Blank and E. Findl (eds.); Plenum Press, New York (1987) 271.
36. Gos, P., Eicher, B.et al. Bioelectromagnetics 18 (1997) 142.
37. Gos, P., Eicher, B.et al. Bioelectromagnetics 21 (2000) 515.
38. Grundler, W., Keilmann, F. Z. f. Naturforsch. 44c (89) 863.
39. Hamblin, D. L., Wood, A. W. Int. J. Radiat. Biol. 78 (2002) 659.
40. Hamblin, D. L., Wood, A. W.et al. Clinical Neurophysiology 115 (2004) 171.
41. Hardell, L., Hallquist, A.et al. Europ. J. Cancer Prevention 11 (2002) 377.
42. Hardell, L., Mild, K. H.et al. Intern. J. Oncology 22 (2003) 399.
43. Hardell, L., Näsman, Å.et al. Intern. J. Oncology 15 (99) 113.
44. Hata, K., Yamaguchi, H.et al. Bioelectromagnetics 26 (2005) 49
45. Heikkinen, P., Kosma, V. M.et al. Intern. J. Radiat. Biol. 79 (2003) 221.
46. Heynick, L. N., Johnston, S. A.et al. Bioelectromagnetics Suppl. 6 (2003) S74-S100.
47. Hirose, H., Sakuma, N.et al. Bioelectromagnetics 28 (2007) 99.
48. Hirose, H., Sakuma, N.et al. Bioelectromagnetics 27 (2006) 494.
49. Hocking, B., Gordon, I. R.et al. Med. J. Aust. 165 (96) 601.
50. Hoytö, A., Sihvonen, A.-P.et al. Radiat. Environ. Biophys. 45 (2006) 231.
51. Huber, R., Treyer, V.et al. J. Sleep Res. 11 (2002) 289.
52. Huber, R., Treyer, V.et al. Europ. J. Neuroscie. 21 (2005) 1000.
53. Ihrig, I., Heese, C.et al. Bioelectromagnetics 18 (1997) 595.
54. Inskip, P. D., Tarone, R. E.et al. N-Engl-J-Med 344 (2001) 79.
55. Kheifets, L. I. Bioelectromagnetics S5 (2001) S120-S131.
56. Klitzing, I. von. Physica Medica 11 (95) 77.
57. Koyu, A., Cesur, G.et al. Toxicology Letters 157 (2005) 257.
58. Krause, C. M., Bjornberg, C. H.et al. Intern. J. Radiat. Biol. 82 (2006) 443.
59. Lahkola, A., Auvinen, A.et al. Int. J. Cancer 120 (2007) 1769.
60. Lantow, M., Schuderer, J.et al. Radiat. Res. 165 (2006) 88.
61. Leszczynski, D., Joenvaara, S.et al. Differentiation 70 (2002) 120.
62. Leszczynski, D., Metz, M. L. Proteomics 6 (2006) 4674.
63. Liboff, A. R. In: A. Chiabrera et al. (eds.), Plenum, London (1985) 281.
64. Liburdy, R. P., Vanek, P. F. Radiat. Res. 102 (1985) 190.
65. Litovitz, T. A. Bioelectrochem. Bioenerg. 46 (1998) 303.
66. Litovitz, T. A., Krause, D.et al. Bioelectromagnetics 14 (93) 395.
67. Lonn, S., Ahlbom, A.et al. Am. J. Epidem. 164 (2006) 637.
68. Lönn S, Forssen Uet al. Occup Environ Med 61 (2004) 769.
69. Mascarinec, G., Cooper, J.et al. J. Environ. Pathol. Toxicol. Oncol. 13 (94) 33.
70. McKenzie, D. R., Yin, Y.et al. Austral. New Zealand J. Pub. Health 22 (98) 360.
71. Merritt, J. H., Shelton, W. W. Chamness A. F. Bioelectromagnetics 3 (82) 475.
72. Morgan, R. W., Kelsh, M. A.et al. Epidemiology 11 (2000) 118.
73. Mullins, J. M., Litovitz, T. A.et al. Bioelectrochem. Bioenerg. 44 (98)
74. Muscat, J. E., Malkin, M. G.et al. Neurology 58 (2002) 1304.
75. Muscat, J. E., Malkin, M. G.et al. JAMA 284 (2000) 3001.
76. Navarro, E. A., Segura, J.et al. Electromagnetic Biology and Medicine 22 (2003) 161.
77. Neubauer, G., Feychting, M.et al. Bioelectromagnetics 28 (2007) 224.
78. Oktem, F., Ozguner, F.et al. Arch. Med. Res. 36 (2005) 350.
79. Ozguner, F., Bardak, Y.et al. Mol. Cell. Biochem. 282 (2006) 83.
80. Panagopoulos, D. J., Chavdoula, E. D.et al. Mutat. Res.-Genetic Toxicol. Environ. Mutag. 626 (2007) 69.
81. Penafiel, L. M., Litovitz, T.et al. Bioelectromagnetics 18 (97) 132.
82. Pickard, W. F., Moros, E. G. Bioelectromagnetics 22 (2001) 97.
83. Prohofsky, E. W. Bioelectromagnetics 25 (2004) 441.
84. Repacholi, M. H., Basten, A.et al. Radiat. Res. 147 (97) 631.
85. Röschke, J., Mann, K. Bioelectromagnetics 18 (97) 172.
86. Rothman, K. J., Chou, C. K.et al. Epidemiology 7 (96) 291.
87. Schüz, J., Johansen Ch. Bioelectromagnetics 28 (2007) 130.
88. Simko, A., Hartwig, C.et al. Toxicology Letters 161 (2006) 73.
89. Speit, G., Schuetz, P.et al. Mutat. Res.-Genetic Toxicol. Environ. Mutag. 626 (2007) 42.
90. Sukhotina, I., Streckert, J. R.et al. J. Pineal Res. 40 (2006) 86.
91. Sun, L. X., Yao, K.et al. Mutat. Res.-Fund. Mol. Mech. Mutag. 602 (2006) 135.
92. Szmigielski, S. Sci. Total Environ. 180 (96) 9.
93. Utteridge, T. D., Gebski, V.et al. Radiat. Res. 158 (2002) 000.
94. Vanderwaal, R. P., Cha, B.et al. Intern. J. Hyperthermia 22 (2006) 507.
95. Vijayalaxmi. Radiat. Res. 166 (2006) 532.
96. Vrijheid M, Deltour Iet al. J Expo Sci Environ Epidemiol (2006)
97. Wagner, P., Röschke, J.et al. Bioelectromagnetics 19 (98) 199.
98. Wang, J., Koyama, S.et al. Bioelectromagnetics 27 (2006) 479.
99. Weisbrot, D., Lin, H.et al. J. Cell. Biochem. 89 (2003) 48.
100. Wilén, J., Sandström, M.et al. Bioelectromagnetics 24 (2003) 152.
101. Wood, A. W. Archives of Disease in Childhood 91 (2006) 361.
102. Zmyslony, M., Palus, J.et al. Bioelectromagnetics 25 (2004) 560.

Prof. em. Dr. rer nat. habil. Roland Glaser was Chair of Biophysics at the Humboldt University of Berlin. Prof. Glaser is a member of the working group „high-frequency microsodosimetry“ of the German Commission for Radiation Protection.

The relevance in EM

by Joachim Schüz

There are now more than 30 original publications in the scientific literature on the question whether the use of mobile phones increases the brain tumour risk. The results regarding short-term and moderate use of mobile phones are relatively clear. Obviously, an association with brain tumour risk can be excluded. The situation is not so clear regarding long-term use of mobile phones over ten or more years. However, evidence against a strong increase in risk is growing. As even very large studies include only cancer patients, which were diagnosed in 2003 or before, the proportion of long-term users (especially of the GSM technology) is small in both the completed and the ongoing studies, especially if risks of subgroups, e.g. tumours in the lateral areas of the brain, are to be investigated. Methodological limitations of the studies conducted so far need to be discussed. This topic poses a special challenge, as the survey of mobile phone use is complicated and even if it is obtained with certain reliability, it is still only a proxy of the actual exposure of interest, namely radio frequency electromagnetic fields. Moreover the disease to be investigated is very serious, often associated with a restriction of cognitive abilities in the patients. A comprehensive prospective study in the sense of an active surveillance system offers the possibility to accompany the wider distribution and the newly emerging technologies in mobile telecommunication under health-relevant aspects.

# of epidemiological studies
CE research

Epidemiology – a definition

Epidemiology deals with the spatial and temporal distribution of diseases in the population and the factors that have a causal influence on it. It thus comprises both the description of disease incidence (descriptive epidemiology) and the search for causes (analytic epidemiology), mainly in the framework of observational studies. The aim is to identify risk factors and contribute to the prevention of diseases.

The strength of epidemiological studies is that they capture real situations, i.e. the exposure is investigated under the conditions of everyday life in persons who actually are exposed. Some human experiments cannot be performed in laboratory studies and the extrapolation of observations in cells or animals to humans is not always possible. Moreover epidemiological research has the advantage that the relevance of an effect can be assessed on the level of the whole population. The observational character of epidemiological studies, however, has also disadvantages insofar that the researcher cannot control the study conditions. Therefore spurious associations can appear in epidemiological studies, e.g. by false correlations via third factors (confounders) or inappropriate group comparisons.

The evaluation of epidemiological evidence is performed under different aspects: the strength of the observed association, the consistency of results within a study and across different studies, the occurrence of a dose-response relationship as well as the biological plausibility of results (criteria as given by Hill, 1965). A special problem in the interpretation of observed associations arises when epidemiological findings are not supported by experimental studies. One reason could be that epidemiology is an early indicator for an association, which is uncovered in laboratory studies because the underlying mechanism is unknown, or was not modelled correctly. Another reason could be that the empirically observed association is not causal. Epidemiological and experimental studies supplement each other and should always be discussed together.

Studies on mobile phones and brain tumours

There are now more than 30 original publications on the question whether mobile phone usage increases the risk of brain tumours, even after leaving out numerous letters and reviews regarding the topic. These publications can be subdivided into four groups (table 1). The **first group** comprises the studies published around the turn of the century, which were independent case-control studies from the USA and Scandinavia, performed in patients ascertained already in the nineties, i.e. the percentage of persons with mobile phone usage of more than five years was low. In summary, these studies provided no evidence that short-term mobile phone use is associated with the brain tumour risk. The **second group** is a series of case-control studies performed in parts of Sweden (three subsequent studies using the same methodology), which were published several times under partially different aspects. In a review paper by the research group who conducted these studies, a strong association between both mobile phone use and the use of cordless phones with the brain tumour risk was reported, which was most pronounced for high-grade gliomas and acoustic neuromas, but was also

found for low-grade gliomas and meningiomas. In these studies an increased risk was observed with long-term and more frequent phone use, but statistically significantly increased risks were also seen at rather moderate use patterns, i.e. already at life-time cumulative mobile phone usage between 1 and 43 hours. The **third group** is the so-called "Interphone study", an international case-control study involving 16 centres in 13 countries. Beside Germany, the participating countries were Australia, Canada, Denmark, Finland, France, Great Britain, Israel, Italy, Japan, New Zealand, Norway and Sweden; approximately 1-hour interviews with 2765 glioma patients, 2425 meningioma patients, 1121 acoustic neuroma patients and 109 patients with malignant salivary gland tumours as well as 7658 control persons were conducted. All centres worked in accordance with an international study protocol, which allows joint analyses when the study will be completed. This pooled analyses and the large study size also allow to gain insight into possible risks among subgroups of patients, e.g. according to the type of the tumour and its localization; the latter is important because, due to the low penetration depth of radio frequency electromagnetic fields emitted by the phone, it is conceivable that an increase in risk can only be found in tumours located in the lateral area of the side of the head where the phone was held. In the meantime, more than one half of the data from the Interphone study have been published, including the studies from four Scandinavian countries, from Great Britain, from Japan and Germany. They confirm the results of the first group of no association with short-term use and contradict the second group, which has found that even short-term mobile phone use increases the risk. The results for the group of long-term users (ten years or longer) are still unclear. There is evidence of an increased risk of acoustic neuroma from Sweden, of an increased risk of glioma from Germany, keeping in mind that combining all published Interphone components weakened these single findings. The results of the joint analyses need to be awaited before drawing further conclusions. The **fourth group** is formed by a study of different design (cohort study). In a Danish study the entire adult population was divided in two groups, into those who had their first mobile phone contract in their own name between 1982 and 1995, and into all others. Cancer incidence rates were calculated for these two population groups using the Danish Cancer Registry. The incidence rates for brain tumours, leukemias, eye and salivary gland tumours were not increased in the early mobile phone owners. Due to the rather rough division into exposed and unexposed persons, a moderately increased risk cannot be excluded in this type of study, but having missed a substantial risk increase is very unlikely. Hence, the results do contradict the observed increase in risk of the second group. For a discussion of these studies and their evaluation please refer to a recent opinion statement of the European Union (download is for free from the internet [1]). A short review in German was recently published by the Deutsches Ärzteblatt [2]. In the following, the methodological challenges of these studies will be examined in more detail.

Case-control studies – advantages and disadvantages

Case-control studies are based on the comparison of two groups of persons (fig. 1). The group of cases are the persons who have the target disease of the study and they are retrospectively examined for the occurrence of the possible risk factors of interest. A control group of persons without the disease is examined likewise. The direction of the investigation is always retrospective (the starting point is the disease), regardless of the fact whether the case identification was retrospective as well (the diagnosis was made prior to the beginning of the study; prevalent cases) or prospective (after the beginning of the study over a defined time period newly diagnosed cases are included in the study; incident cases). A prospective recruiting of patients is necessary for outcomes with poor prognosis. Case-control studies are based on one or few diseases, but a great number of potential risk factors are examined. Despite some disadvantages, case-control studies are very common in the epidemiology of chronic diseases, especially for rare outcomes. The conduct of case-control studies is usually shorter than that of cohort studies and

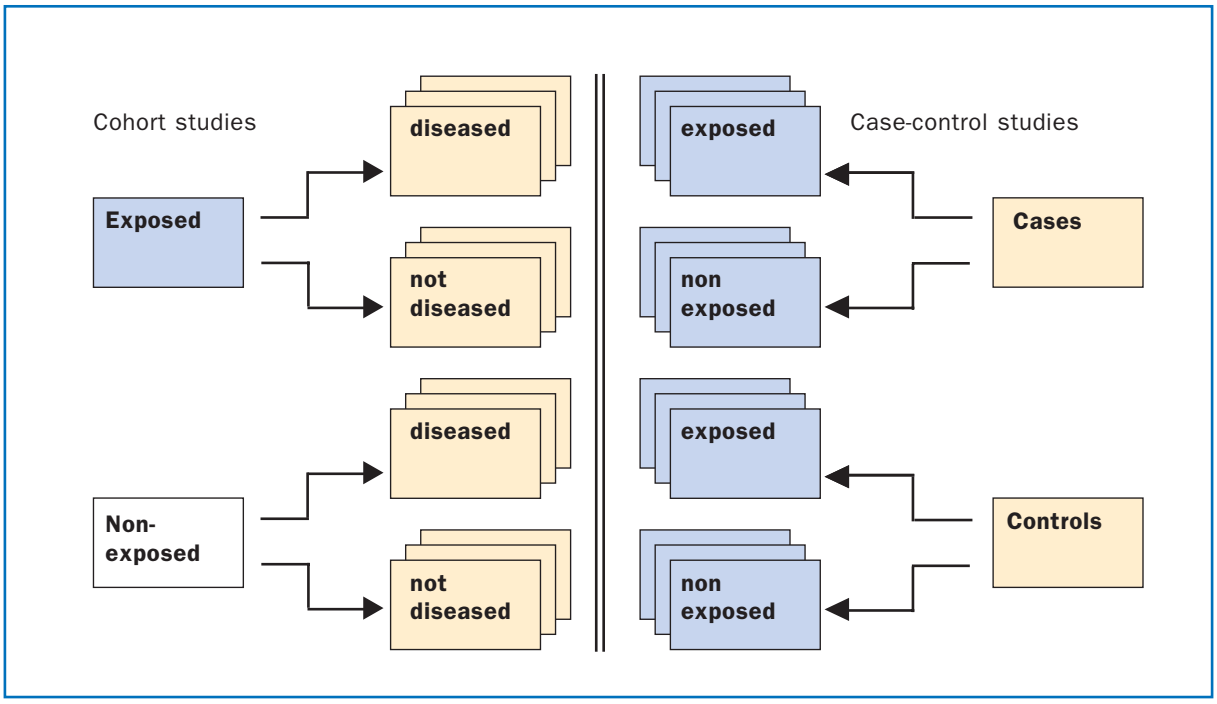


Figure 1: Overview of the designs of cohort studies and case-control studies

their sample size is smaller (see "The Danish cohort study – advantages and disadvantages"). Difficulties of case-control studies are the recruiting of representative samples and the quality of the retrospective exposure assessment.

For exposure assessments based on questionnaires the contact with the participants is necessary and prior to the interview participants need to sign informed consent. While the willingness to participate is usually high in the "case" group, many refusals will appear in the "control" group, despite of intensive persuasive efforts. An example for this is the Interphone study component in Germany, where, despite several invitation letters, the provision of comprehensive information material and manifold personal contacts, a participation rate of 62 % was reached; this was a convenient response rate for a case-control study, but still means that each third potential volunteer randomly selected from population files, could not be persuaded to cooperate [3]. The low willingness to participate becomes a problem if it is systematic, and there is often an education gradient regarding the willingness to participate. This education gradient again correlates with life style factors and occupational exposures, which can result in distortions regarding these factors in risk estimation. A short questionnaire with non-participants used for Interphone (answered by about half of this group) showed a deficit of participants without mobile phone [3] that may have resulted in a bias towards a spurious protective effect.

Epidemiological studies often aim at exposures that happened years in the past, and the assessment of such exposures via questionnaire is another crucial disadvantage of case-control studies. First, because it is generally difficult to recall past events; e.g., the first question on mobile phone use in Interphone was when (year and month) regular mobile phone use began, defined as at least one call per week over a period of at least half a year. Second, because the disease itself affects the memory abilities. A validation study within Interphone [4], where network traffic data were compared to self-reported data of volunteers, showed great deviations even regarding current usage. On average, participants overestimated the length of phone calls by 40 %. When such reporting errors are equal in cases and controls, it is expected to lead to an underestimation of risk. A spuri-

ous risk is produced when patients tend to overestimate more strongly than the control persons; a bias often observed in case-control studies.

Already in the first case-control studies on mobile phone use, the questions regarding the side of the head to which the mobile phone was usually held where identified as problematic. The association observed in many studies with ipsilateral use (preferred side of the head during usage is the side of the head with the tumour) was balanced by a protective effect on the contralateral effect [e.g. 5 and 6]. In the joint evaluation of Interphone this will be taken one step further. The affected side of the head will be subdivided into smaller areas according to exposure intensity: if the ipsilateral effect is equally strong for all areas (like frontal, temporal and occipital), this rather indicates evidence of an interview artefact, but if it is stronger for areas with higher exposure (temporal and/or parietal), it may indicate a causal association.

The Danish cohort study – advantages and disadvantages

The basis of a cohort study is a population of non-diseased persons, which is divided into two or more groups according to the exposure of interest (figure 1). After a defined follow up period, the disease incidence rates are compared across these groups. Often also a cohort of exposed persons is created, whose disease incidence rate is then compared with that of the general population. The direction of the investigation is always prospective (the starting point is the exposure), regardless of the fact whether the entire study was planned prospectively, i.e. the cohort is set up at the beginning of the study, or whether it is a historical cohort study. A historical cohort study is possible when data from the past are available, which retrospectively allows the reconstruction of cohorts. Cohort studies comprise few risk factors, but allow the examination of a great number of diseases potentially associated with these risk factors. The etiologically adequate direction of cohort studies makes them the type of study with the greatest power. As exposure is obtained prior to the disease, the assumption of a causal relation is stronger than in case-control studies. In spite of that, prospective cohort studies are an exception in the epidemiology of chronic diseases. The reason for that is the great expenditure. A very large cohort has to be formed for rare diseases and the follow up has to be done for a very long time period.

This aspect is an advantage of the Danish concept [7]. Based on customer data of all Danish network

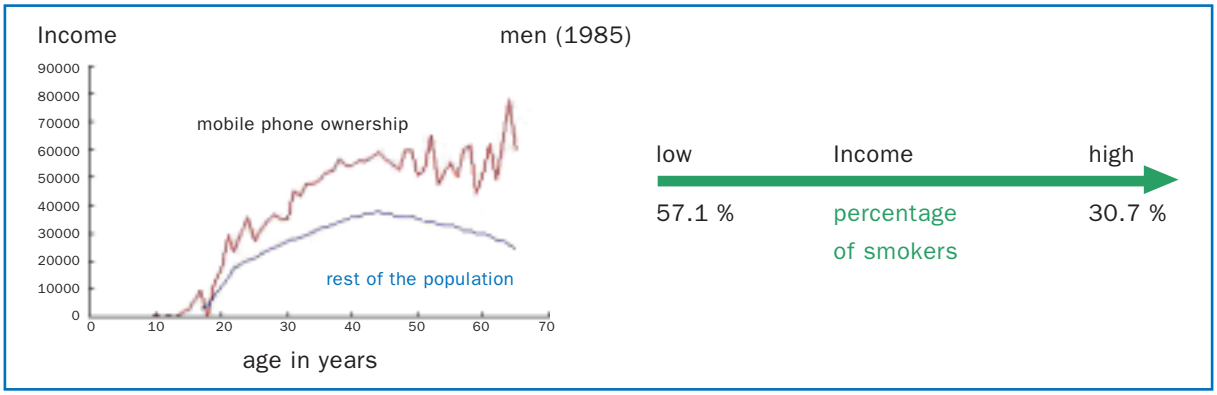


Figure 2: Spurious associations produced by a third factor: due to the correlations between early mobile phone ownership (1985) and income and between income and smoking behaviour, the proportion of smokers was lower in the cohort of mobile phone owners than in the rest of the population; hence, mobile phone ownership displayed a false protective effect on the risks of diseases associated with smoking.

operators, a cohort of 420,000 adult Danes was set up comprising mobile phone owners between 1982 and 1995. This cohort was followed up to 2002 and the cancer incidence rates of the cohort were compared with the rates of rest of the Danish population. Thus, the study is maximally representative for Denmark (the whole country was included) and has a maximal length with respect to the study period (up to 21 years), even when the average usage was only 8.5 years and the percentage of mobile phone owners of ten and more years was just 56,000 persons. A disadvantage is the rough categorization of exposure. The person with the mobile phone contract is not necessarily the mobile phone user, on the other hand there are users who have no contract in their own name (family members or contracts in the name of the company). The Danish study has no information on prepaid phones and whether car phones or handsfree kits or speakerphones were used. Moreover the exposure cannot be divided according to the frequency of use, therefore rare users and intense users are in the same exposure category. All these disadvantages can lead to an underestimation of risk, if any. If an association would have been observed in this study, it could not be explained by these restrictions. But an inconspicuous finding could mean that there was no association or that a moderate increase in risk has been missed. An evaluation of the quality of the exposure measure [8] shows that, with the Danish concept, a hypothetical increase in risk by 50 % would have been measured as a 20 % increase.

If the correlation of exposure proxies (here: purchase of a mobile phone contract) and the exposure of interest (here: mobile phone field exposure) is only moderate, the possible role of confounders, which are factors that correlate with the exposure and the disease risk as well, becomes important. The Danish cohort study can, via the purchase of a mobile phone contract, with a certain validity make a prognosis on smoking behaviour, because the cohort of contract owners had a high income and among Danish men high income correlates with smoking behaviour (fig. 2). Cancer types associated with smoking were observed less than expected in the cohort, falsely suggesting a protective effect of mobile phones on e.g. lung cancer. In women, smoking is not associated with high income and the lung cancer rate in the cohort is therefore not lower than expected. Methodologically, these observations support the strength of the design. But an evaluation of the brain tumour risk associated with mobile radio is only possible since smoking and other life style factors are no confounders in this context.

The solution to the problem

A number of outlined problems could be solved with the help of prospective cohort studies. An interview of participants prior to the occurrence of the disease avoids the disease affecting responses in an interview. This would be crucial especially regarding the question for the side of the head preferred during mobile phone usage. In addition, also data of network operators could be collected prospectively, which would objectify the frequency of use. In the interview also data on competing risks could be collected, so that diseases can be examined, where life style is known to have a great influence on the risk profile.

For the investigation of rare diseases a large cohort is required. Estimates suggest about 250,000 persons, so such studies would have to be conducted in a multinational approach to share the burden. This concept of prospective cohorts was piloted in some countries and the design was optimized. Under the heading Cosmos (COhort Study on MObile phone userS) the project starts this year in Denmark and next year in Sweden and England. While participation is still considered in Finland and the Netherlands, the project was cancelled in Germany after the end of the feasibility study. Whereas the feasibility of the concept was also successfully demonstrated in Germany, the willingness to participate in a pilot study was very low (piloted with 5000 volunteers). The resulting costs for establishing a cohort in Germany have persuaded the Federal Government to withdraw from the project.

The Cosmos study can also be seen as a tool of surveillance. Emerging questions can be answered faster and more efficient than when each issue would require an own new study. Other diseases than can-

Author + Journal	country	# exposed cases#	RR (KI)	definition	longterm exposure t	R (KI) cases R
brain tumors						
group 1 (early case-control studies)						
Hardell [6][a]	Sweden (part)	78	1,0 (0,7-1,4)	> 5 years	34	0,8 (0,5-1,4)
Muscat, JAMA, 2000	USA (part)	66	0,8 (0,6-1,2)	≥ 4 years	17	0,7 (0,4-1,4)
Inskip, N Engl J Med, 2001	USA (part)	139	0,8 (0,6-1,1)	≥ 5 years	22	0,7 (0,4-1,4)
Auvinen, Epidemiology, 2002	Finland	40 NMT, 16 GSM	1,3 (0,9-1,8)	> 2 years	17 NMT, 1 GSM	1,5 (0,9-2,5)
group 2 (case-control study series from Sweden)						
Hardell [6][a]	Sweden (part)	-	-	> 10 years	16	1,2 (0,6-2,6)
Hardell [9][b]	Sweden (part)	NMT Gliom GSM Gliom NMT Mening. GSM Mening.	1,5 (1,1-1,9) 1,3 (1,1-1,6) 1,3 (1,0-1,7) 1,6 (1,0-2,6)	> 10 years	NMT Gliom GSM Gliom NMT Meningeom GSM Meningeom	2,4 (1,7-3,5) 3,4 (1,6-7,3) 1,1 (0,9-1,3) 1,8 (0,7-4,6)
group 3 (Interphone case-control study))						
Lönn, Am J Epidemiol, 2005[c]	Sweden	214 Gliom 118 Meningeom	0,8 (0,6-1,0) 0,7 (0,5-0,9)	≥ 10 years	25 Gliom 12 Meningeom	0,9 (0,5-1,5) 0,9 (0,4-1,9)
Christensen, Neurology, 2005[c]	Denmark	59 Gliom (high) 47 Gliom (low) 67 Meningeom	0,6 (0,4-0,9) 1,1 (0,6-2,0) 0,8 (0,5-1,3)	≥ 10 years	8 Gliom(high) 6 Gliom(low) 6 Meningeom	0,5 (0,2-1,3) 1,6 (0,4-6,1) 1,0 (0,3-3,2)
Hepworth, BMJ, 2006[c]	Great Britain (part)	508 Gliom	0,9 (0,8-1,1)	≥ 10 years	66 Gliom	0,9 (0,6-1,3)
Klaeboe, Eur J Cancer Prev, 2007[c]	Norway	161 Gliom 96 Meningeom	0,6 (0,4-0,9) 0,8 (0,5-1,1)	≥ 6 years	55 Gliom 28 Meningeom	0,7 (0,4-1,2) 1,2 (0,6-2,2)
Lahkola [5][c]	Denmark, Finland, Norway, Sweden, Great Britain (part)	867 Gliom	0,8 (0,7-0,9)	≥ 10 years	88 Gliom	0,9 (0,7-1,3)
Schüz [3]	Germany	138 Gliom 104 Meningeom	0,8 (0,6-1,1) 1,0 (0,7-1,3)	≥ 10 years ≥ 10 years	12 Gliom 5 Meningeom	2,2 (0,9-5,1) 1,1 (0,4-3,4)
group 4 (Danish retrospective cohort study)						
Johansen, J Natl Cancer Inst, 2001[d]	Denmark	154	1,0 (0,8-1,1)	> 5 years	24	1,0 (0,7-1,6)
Schüz [7][d]	Denmark	580	1,0 (0,9-1,1)	≥ 10 years	28	0,7 (0,4-1,0)
acoustic neuromas						
group 1 (early case-control studies)						
Hardell [6][a]	Sweden (part)	5	0,8 (0,1-4,2)	-	-	-
Muscat, Neurology, 2002	USA (part)	-	-	≥ 3 years	11	1,7 (0,5-5,1)
Inskip, N Engl J Med, 2001	USA (part)	22	1,0 (0,5-1,9)	≥ 5 years	5	1,9 (0,6-5,9)
group 2 (case-control study series from Sweden)						
Hardell [9][b]	Scheden (part)	NMT GSM	2,9 (2,0-4,3) 1,5 (1,1-2,1)	> 10 years	NMT GSM	3,2 (1,7-6,1) 0,8 (0,1-6,6)
group 3 (Interphone case-control study)						
Christensen, Am J Epidemiol, 2004[e]	Denmark	45	0,9 (0,5-1,6)	≥ 10 years	2	0,2 (0,0-1,1)
Lönn, Epidemiology, 2004[e]	Sweden	89	1,0 (0,6-1,5)	≥ 10 years	14	1,9 (0,9-4,1)
Klaeboe, Eur J Cancer Prev, 2007[e]	Norway	22	0,5 (0,2-1,0)	≥ 6 years	7	0,5 (0,2-1,5)
Schoemaker [10][e]	Denmark, Finland, Norway, Sweden, Great Britain (part)	360	0,9 (0,7-1,1)	≥ 10 years	47	1,0 (0,7-1,5)
Schlehofer [11]	Germany	29	0,7 (0,4-1,2)	≥ 5 years	8	0,5 (0,2-1,3)
Takebayashi, Occup Environ Med, 2006	Japan	51	0,7 (0,4-1,2)	> 8 years	4	0,8 (0,2-2,7)
group 4 (Danish retrospective cohort study))						
Johansen, J Natl Cancer Inst, 2001[d]	Denmark	7	0,6 (0,3-1,3)	-	-	-
Schüz [7][d]	Denmark	32	0,7 (0,5-1,0)	-	-	-

[a] idential with the first study from group 1, therefore only > 10 years result taken for group 2
[b] taken from a review of the working group in 2006; the original results are presented in more than a dozen publications of Hardell et al., partially with the same study population; according to the authors, three subsequently performed case-control studies
[c] the glioma results of Lönn, Christensen, Hepworth and Klaeboe are pooled in Lahkola [5] (together with Finland that has not published separately)
[d] Schüz [7] is the publication on the expanded follow-up of the Danish cohort of Johansen (2001)
[e] the acoustic neuroma results of Lönn, Christensen and Klaeboe are pooled in Schoemaker [10] (together with Finland and Great Britain that have not published separately)

Table 1. Overview of epidemiological studies on mobile phone usage and the risk to get brain tumours (adapted and expanded from [1]); shown are groups according to the text, the references, the country, where the study was perforemd, the number of exposed cases with the estimated relative risk (incl. 95 % confidence interval) for overall mobile phone use and the number of exposed cases with the estimated risk (incl. 95% confidence interval) for long-term users as well as the corresponding definition of longterm use.

cer were not examined in mobile phone studies so far. The biggest challenge for the Cosmos study is the constantly changing technology and the question how to measure relevant differences of exposure across the population in the future.

Outlook

The rapid spreading of mobile phones at the end of the nineties and the development towards cheaper prices for making calls resulted in a high popularity of mobile phones. Innovative concepts like "flat rates", "home zones", multifunctional mobile phones and the replacement of traditional phones at home by cordless phones contribute to the development that mobile phone users use the phone more frequently, that they have begun to use phones at an earlier age and that they have phoned more than the typical users of epidemiological studies performed today. "Flat rates", which almost allow mobile phone usage without limits, stand in contrast with the observation that e.g. in the German component of the Interphone study a user with a life-time cumulative 195 hours of usage belongs to the intensive mobile phone user group [3]. Another noteworthy trend however is that the microwave exposure from the phone became much lower over time and will most likely again be lower with the expansion of UMTS networks.

When considering all epidemiological studies completed until now, which all speak against an at least substantial cancer risk, together with the numerous experimental studies primarily speaking against adverse health effects, it seems unlikely that new national small epidemiological studies will provide new insights. Multicenter studies with a common protocol and a sufficient size of study, as e.g. the Cosmos study, have all the advantages to verify the available knowledge and to respond flexibly to new hypothesis. The popularity of the mobile telecommunication technology and its constant development require a continuous scientific monitoring of adverse health consequences, which is where epidemiology can play a key role.

References

- *[1] Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Possible effects of Electromagnetic Fields (EMF)on Human Health. EC Directorate-General Health & Consumer Protection [http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf].*
- *[2] Blettner M, Schüz J. Handy und Gehirntumor: Einzelne Ergebnisse werden aus dem Zusammenhang gerissen. Dtsch Ärztebl 2007; 104:A-536-39*
- *[3] Schüz J, Böhler E, Berg G, et al. Cellular phones, cordless phones, and the risk of gliomas and meningiomas (Interphone study group, Germany). Am J Epidemiol 2006, 163: 512-20*
- *[4] Vrijheid M, Cardis E, Armstrong BK, et al. Validation of short term recall of mobile phone use for the Interphone study. Occup Environ Med 2006, 63: 237-43*
- *[5] Lahkola A, Auvinen A, Raitanen J, et al. Mobile phone use and risk of glioma in 5 North European countries. Int J Cancer 2007; 120:1769-75*
- *[6] Hardell L, Nasman A, Pahlson A, et al. Use of cellular telephones and the risk for brain tumors: A case-control study. Int J Oncol 1999;15:113-6.*
- *[7] Schüz J, Jacobsen R, Olsen JH, et al. Cellular telephone use and cancer risk: an update of a nationwide Danish cohort. J Natl Cancer Inst 2006; 98: 1707-13*
- *[8] Schüz J, Johansen C. A comparison of self-reported cellular telephone use with subscriber data: agreement between the two methods and implications for risk estimation. Bioelectromagnetics 2007; 28: 130-136*
- *[9] Hardell L, Mild KH, Carlberg M, Söderqvist F. Tumour risk associated with use of cellular telephones or cordless desktop telephones. World J Surg Oncol 2006;4:74*
- *[10] Schoemaker MJ, Swerdlow AJ, Ahlbom A, et al. Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries. Br J Cancer 2005; 93:842-8.*
- *[11] Schlehofer B, Schlaefer K, Blettner M, et al. Environmental risk factors for sporadic acoustic neuroma (Interphone Study Group, Germany). Eur J Cancer 2007; 43:1741-7*

Dr. rer. physiol. et med. habil. Joachim Schüz is Head of the Department of Biostatistics and Epidemiology at the Institute of Cancer Epidemiology, Danish Cancer Society, Copenhagen, Denmark. He is a member of the Board of Directors of the Bioelectromagnetic Society and member of the Working Group on EMF of the EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR).

Insights from experimental

by Alexander Lerchl

The question whether high-frequency electromagnetic fields are health-relevant or not, is still controversially discussed. Since the introduction of mobile communication by private persons this discussion has expanded considerably. Huge parts of the population think that health hazards exist and are critical of mobile radio operators and manufacturers of end devices. The only way to react to the fears in the population is to initiate scientific investigations that are cleanly performed and which examine possible dangers on all relevant levels. Besides biophysical investigations on membranes, especially investigations in cells, animals and humans are necessary to assess both possible mechanism and consequences for the whole organism.

EMCE research

In principle, high-frequency electromagnetic fields (HF-EMF) in the frequency range of mobile communication are not able to ionize and thus cause direct changes in molecules or atoms. They are therefore fundamentally different from ionizing radiation, which provokes damages already at smallest radiation doses. The only established effect of HF-EMF is thermal, i.e. tissue is more or less heated by the absorption of these fields. This fact on one hand is the basis for the setting of limits, on the other hand the focus of discussions about **non-thermal effects** of HF-EMF, repeatedly postulated and seemingly confirmed by single studies.

To investigate health effects of HF-EMF, biological experiments in cells and whole organism have to be conducted in order to examine both possible interaction mechanisms and effects which cannot be determined in single cells alone, e.g. tumour initiation or promotion. Investigations in cells are oriented to processes, which e.g. comprise the expression of certain genes or physiological responses that can be examined by light microscopy. At any rate, possible HF-EMF effects should be examined both in cells and in whole organisms to compare possible effects. Without this basic research, epidemiological studies lack the fundamental prerequisite to see results, if there is a damaging effect, in relation to the overall context.

Experiments on biological effects of HF-EMF necessarily are interdisciplinary. While earlier studies on this topic were performed with very simple technical means, exposure quality and dosimetry were considerably improved in recent years. The high technological standard of present investigations ensures that unintended "hot spots" are avoided, meaning areas of very high exposure falsifying the overall result. The study that is perhaps best known is by Repacholi and colleagues [1], where mice were exposed to a high-frequency electromagnetic field at 900 MHz showed an increased leukemia rate. By the arrangement of antennas and the cages extremely high variations of the specific absorption rare (SAR) were reached, which varied by a factor of 500 across the animals. A replication study by Utteridge and colleagues with considerably improved exposure conditions and a much smaller variation of SARs could not confirm the results [2]. Other studies could find no evidence of HF-EMF accelerating leukemia development in mice either [3; 4].

Another criterium for the acknowledgement of a non-thermal effect of HF-EMF on biological systems is the replicability of results. Due to statistical laws and biological variances, random positive results can be expected which, per se, require no consequences. Only when single results can be reproduced independently, taking measures (e.g. the decrease of existing exposure limits) would be legitimized.

It should be standard today as well that experiments are conducted blinded and with adequate controls (sham exposure, perhaps cage controls). These requirements are not trivial technically, as the exposure systems (for exposure and non-exposure) must be optically identical and in each other respect, except for the existence of an electromagnetic field. Only under these conditions, and if the users do not know which animals and cells, respectively, are exposed, conscious or unconscious influences on results are excluded. Unfortunately, this standard is still not fully established. Repeatedly, studies are submitted and published, where the conditions under exposure and sham exposure considerably differ and effects other than those from HF-EMF cannot be excluded. It is e.g. technically and methodologically not acceptable, to irradiate rats with a rebuilt microwave oven, as it was done in 2006 by Trosic and colleagues [5]. The exposure conditions not only are less than

optimal, also other influential factors, especially noise, could have led to considerable effects. It is evident that the tests were not blinded.

But also negative results, i.e. lacking evidence of biological effects of HF-EMF should be viewed critically sometimes. Anane and colleagues e.g. could find no evidence of additional adverse effects in rats in which, by the application of a carcinogen, breast cancer was induced [6]. The group size of 16 animals was too small to provide evidence of effects. The statistical power of investigated parameters in such investigations has to be calculated prior to experiments so as to ensure sufficient power also when negative results are expected. Otherwise such studies are worthless.

Investigations of possible biological effects of HF-EMF require hypotheses, without which the experiments sometimes are like fishing in murky waters. The testing of all possible parameters in order to find effects, is not only doubtful scientifically, but causes a large statistical problem, namely that of the accumulation of significance. If e.g. 10 parameters are investigated, the probability that one or several factors differ "significantly" across exposed and non-exposed objects is very large. One can compensate such accumulated significance by correspondingly tightened statistical tests, but then one has the disadvantage to not discover actual differences. At any rate it is necessary to define the parameters to be investigated based on hypotheses prior to an experiment.

The great majority of investigations to-date performed on possible biological effects of non-thermal HF-EMF, which meet the mentioned qualitative criteria, could not show any damages. This is true for experiments performed, in part over long periods, with cells and animals. The investigations that at first showed effects, could not be confirmed in replication studies, or there are no such studies yet. Although it seems, mainly thanks to considerably improved quality standards, that non-thermal HF-EMF have no adverse health effects, research on this topic cannot be seen as finished, as new technologies (frequency bands, types of modulation) are emerging. Their possible biological effects should be tested before full area coverage is obtained.

References

- *1. Repacholi MH, Basten A, Gebski V et al. Lymphomas in ¼-Pim1 transgenic mice exposed to pulsed 900 Mhz electromagnetic fields. Radiat. Res. 1997;* ***147****:631-640.*
- *2. Utteridge TD, Gebski V, Finnie JW et al. Long-term exposure of E-mu-Pim1 transgenic mice to 898.4 MHz microwaves does not increase lymphoma incidence. Radiat Res 2002;* ***158****:357-364.*
- *3. Sommer AM, Streckert J, Bitz AK et al. No effects of GSMmodulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice. BMC Cancer 2004;* ***4****:77.*
- *4. Sommer AM, Bitz AK, Streckert J et al. Lymphoma development in mice chronically exposed to UMTS-radiofrequency electromagnetic fields. Radiat Res 2007;* ***168****:72-80.*
- *5. Trosic I, Busljeta I. Erythropoietic dynamic equilibrium in rats maintained after microwave irradiation. Exp Toxicol Pathol 2006;* ***57****:247-251.*
- *6. Anane R, Dulou PE, Taxile M et al. Effects of GSM-900 microwaves on DMBA-induced mammary gland tumors in female Sprague-Dawley rats. Radiat Res 2003;* ***160****:492-497.*

Prof. Dr. Alexander Lerchl is Professor of Biology at the School of Engineering and Science, Jacobs University, Bremen. One focus of his work is the investigation of biological effects of magnetic fields and high-frequency electromagnetic fields. He is a member of the „Non-Ionizing Radiation" Committee of the German Federal Commission for Radiation Protection.

Contributions of the Engineering Sciences to the Research on Possible RF-related Health Effects

by Gernot Schmid

During the last two decades the research activities on possible RF-related health effects caused by modern mobile communication technologies ("EMF research") have been increasingly recognised as a complex inter-disciplinary science, essentially requiring a high degree of both biological/medical as well as engineering expertise. Unfortunately, this kind of recognition was not always given in the past, as can be seen on the basis of several "early" investigations.

I many of these studies focusing on various biological endpoints, including in vitro, in vivo and human studies, sophisticated biological/medical protocols and methodologies were applied. However, many important technical aspects related to the exposure of the test samples/subjects were only poorly addressed, although the basic physical interaction mechanism between radio frequency radiation and biological tissues are known and documented in the scientific literature since the 1950s (even though only based on rather simple models). Intuitively, devices such as commercially available radio handsets or mobile phones or antennas fed by generic RF sources in the „switched on" or "switched off" state, "close to" the test objects/subjects were used as "exposure facilities" without any clear definition of the actual exposure conditions. Mainly driven by the partly inconclusive results provided by many of these early studies, the demand of engineering knowledge in this field of research has been increasingly realised and it became clear that providing well defined exposure conditions for specific test samples or test subjects within a given biological study design requires a considerably high degree of engineering know how. This understanding triggered what one could call a "boom of EMF research related engineering science" in the early 1990s. Experimental methods for measuring the dielectric properties of body tissues have been optimised and enabled the dielectric tabulation of many important body tissues over the entire frequency range relevant in practice. Methodologies for measuring RF absorption in simplified homogeneous body phantoms have been developed and reached production stage within only a few years, such that standardised compliance testing of mobile phones was available almost simultaneously to their steeply increasing world wide propagation. Moreover, the spreading and the advances of personal computer technology, taking place in the same time period, enabled reasonable software implementations of known numerical methods for computational electrodynamics. Especially in this field of „computational dosimetry" the rapid progress, which could be observed in recent years, is impressive. While at the end of the 1980s computational dosimetry was still

EMVU

limited to body models consisting of a few thousand voxels having dimensions of a few centimeters, one decade later, body models consisting of several million cells of size in the range of millimeters were ready and could be handled by the available computational hardware resources. But not only human body models have been developed, but also voxel models of test animals were made available which has to be seen as a milestone with respect to the design of exposure facilities for animal experiments. With these achievements, a tissue specific absorption analysis in test animals and a comparison between the absorption pattern in test animals and in humans under practically relevant exposure conditions were made possible for the first time. Today, a further decade later, a series of CAD-based high resolution body models, developed from MRI scans of both male and female children and adults are available. More than 100 tissue regions can be distinguished in some of these models, and based on currently available personal computer technology, computations with a spatial resolution in the sub-millimeter range and several hundred million voxels are possible. Using appropriately equipped high performance computer or computer cluster computations with more than a billion voxel are feasible today.

Mainly this amazing progress in computational dosimetry led to a significant improvement with respect to the engineering aspects of biological studies in recent years. On the one hand it has become possible to provide evidence for the weaknesses of the exposure concepts and dosimetric methodologies used in many of the early studies, and on the other hand the development of highly sophisticated exposure facilities for specific biological/medical study designs has been enabled, providing not only a qualitative indicator but also a quantitative tissue specific measure of the actual exposure during the experiments. Therefore, since the late 1990s, it is generally accepted that EMF-related biological/medical studies can only provide reliable and scientifically acceptable results, if competent scientist of both the biological/medical and the engineering sciences are working closely together. As a consequence, a tight co-operation of biologists and engineers becomes an essential condition by most EMF research funding agencies, which further led to the development of many highly sophisticated exposure facilities for a variety of studies (in vitro, in vivo, as well as human studies) in recent years. Defined exposure conditions within known boundaries of uncertainty, (double) blinded application of multi-level exposure with high flexibility regarding the time course of the applied RF signal and at the same time keeping the impairment of the test samples/subject at a minimum under precisely controlled environmental conditions have become basic requirements, and are acting as a robust physical basis of state of the art study designs.

A further aspect, not only closely related to the progress of the dosimetric methodologies described above, but also of general importance for the EMF-related research, is the question of achievable (exposure-) uncertainties in typical RF exposure situations. The awareness about the range of uncertainty, the way how its boundaries are quantified, and the derivation of its consequences with respect to the study outcome is frequently used as an important measure of the quality level of a scientific study. Moreover, the definition of uncertainty ranges with respect to exposure assessment in electromagnetic fields plays an essential role in view of setting safety standard for personal exposure. Also in the field of RF exposure-related uncertainty assessment it was again the progress on computational dosimetry, which enabled

many essential insights. Besides the well known basic propagation properties of electromagnetic fields and the complex spatial and temporal inhomogeneous field distributions connected to them, as well as the complex interaction mechanisms in the near field of antennas, the biological variance of the human anatomy and tissues has been identified as an important uncertainty contributor. When additionally taking into account, as usual in daily life situations, "uncontrolled" exposure conditions, in which additional variations of the resulting exposure are caused by transmit power control, complex medium access- and duplex schemes as implemented in modern mobile communication devices, it becomes obvious that the total uncertainty in exposure assessment (with respect to power absorption) can reach easily more than one order of magnitude under general conditions. Even higher uncertainties must be expected, if the RF-induced temperature elevation in the tissue, which is currently seen as the biologically relevant quantity, is of interest. In this case further significant uncertainty contributors as thermal tissue properties and, most important, the active thermoregulatory response of the organism need to be additionally taken into account. Today, under controlled conditions, as it is the case in well designed biological/medical studies using one of the above mentioned high tech exposure facilities, the resulting uncertainties can at least be kept within a range required for a serious interpretation of the study results. A reliable exposure assessment with a known minimum uncertainty under uncontrolled conditions including multi source exposure, as usual in practice, however, is still one of the present challenges of the EMF research-related engineering science.

From the above it can be recognised that the uncertainty assessment in RF dosimetry is not a problem to be solved straightforward, but that its scope has been shifted during the last two decades. While at the beginning the focus was on uncertainties due to simplified body models and limited computational resources, the progress in computational dosimetry led to an decrease of its inherent uncertainties on the one hand and to the identification of other significant uncertainty contributors on the other hand. Not only this situations shows that there is still demand for further engineering activities in EMF related research. Despite of extending the currently available methodologies to new frequency ranges and exposure conditions to be expected in future, the issue of a reliable analysis of complex (i.e., real) exposure situations based on the biologically relevant quantities appears to be one of the most challenging fields for future EMF research related engineering tasks. For example, embedding the classical electrodynamics-based RF-dosimetry into multi-physics models in connection with statistical methods might be one of the next steps, which can bring benefits to the macroscopic exposure assessment and, moreover, which might also bring new insights in the area of microdosimetry, i.e., the assessment of possible interaction mechanisms on the cellular level.

Dipl.-Ing. Gernot Schmid is the Deputy Area Manager „Mobile Communication Safety" of the Austrian Research Centers GmbH-ARC. His focus of work is the field of experimental and numerical dosimetry in the range of high-frequency and microwaves as well as the development of exposure systems for biological experiments.

"The situation is hopeless, but not serious."
Paul Watzlawick

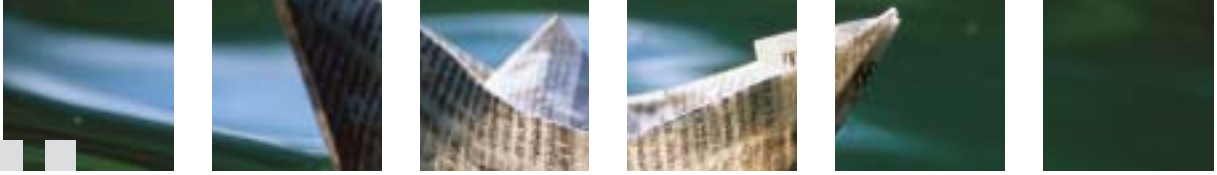
The media – a hysterical hype machine in the EMF debate?

by Peter Wiedemann

More than 30 years ago Paul Watzlawick – known from his essay „The Pursuit of Unhappiness" – has written a book on solutions. In this book, he shows that ways intended to solve a problem may contribute to the problem – sometimes they considerably intensify the problem. For instance, too much safety produces repression; too much chocolate – usually considered as a mood enhancer – leads to nausea; foreign military forces invading another country to pacify it may intensify the fights. The issue is: When you get "more of the good stuff" it quickly becomes „too much":

In this dialectical perspective I will talk about whether and how the media produce social technophobia, especially, whether they amplify concerns and fears regarding wireless telephony. In short, I will talk about the mobile phone dilemma: By this I mean the contradiction between factual acceptance (nearly everyone has a mobile phone, many even two) and the concerns over risks in the public. One could object that it cannot be so bad.

- Despite intensive efforts, science has found no hard scientific facts showing a risk from mobile communication – and the FEMU database comprises 10951 publications on the effects of electromagnetic fields[1].
- Moreover, the story of mobile phones is an unprecedented victory: nothing has changed everyday life as much as the mobile phone, apart from the internet and the personal computer.
- In addition, we can see that the system "Mobile communication in society" is robust – until now it could not be lifted off its hinges, despite all fears over risks.
  The system is working, but not loved – however, must we love it? Some may argue, that wireless telephony is about considerable investment, and a huge number of work places
- in short, the future of a key technology is at stake.



Therefore, caution is needed, because scaremongering is no trivial offence. So back to the question: are the media the culprit? Doubtlessly, daily newspapers like "Bild" in Germany or "Sun" in the UK repeatedly contribute to public concerns. However, it is my opinion that scolding the media is not really a way to solve the problem. Perhaps there is good reason that media are the way they are; according to the famous dictum of Hegel from his preface to Philosophy of Right (1821): "Was vernünftig ist, das ist wirklich; und was wirklich ist, das ist vernünftig." in English: "What is reasonable, is real; that which is real, is reasonable."

I will try to look into this in more detail:

- First, we have to accept that media are not only drivers, but also driven in a game that is inscrutable also for them. Media are driven insofar as they have to orient their messages – according to the key/keyhole principle – to the users of information.
- Second, because media need resonance, their "worst case" is not a false message, but boring contents and the lack of interest which do not encourage to buy.
- Third, since Sigmund Freud we know that human behaviour is controlled by unconscious drives and passions. Of course, the same goes for the users of media.

That's why media are what they are: They have to satisfy the curiosity, the voyeurism, the passion for sensations and for excitement of fear – in Freuds' terminology for the "Angstlust" – of the media consumers. This is a fact that must be considered, if wanting to understand the controversy on mobile phones better. But sometimes this issue is ignored or forgotten. In our political discussion about how to solve the mobile phone controversy, in particular how to enhance public acceptance of cell phone towers, we tend to start from on idealized understanding of the role of the public. It is the concept of a rational citizen responsibly dealing with risks. And it is the conviction that we can solve all problems in a fair and open discourse. To give you one example: In 2005, the former German minister Jürgen Trittin – former head of the federal ministry for the environment – suggested that even for controversial cases, the mobile network operators should engage in more discussions with the local authority representatives as well as with actively involved citizens ..." (Press release BMU & BMWA, Nr. 075/05). Of course, this view is politically correct, but unfortunately, a counterfactual description. It ignores the power of emotions. Media consumers want to be entertained. Entertainment however means to address emotions. Crying and laughing with the news, that is the motto. Moreover – and this is a hard fact of human psychology – the uncommon and the negative news bring attention. Everyone knows: "Women bites dog" brings more attention than "dog bites woman." Further, the human information processing of risk information has some special characteristics that will be briefly outlined in the following:

- Cognitive psychology has shown that numbers have a less sustainable effect than words, and words are less sustainable than images where judgements and decisions are needed. An example: The willingness to spend money increases when the dramatic fate of one refugee is described, including images. Statistics – the description of the general misery – is barely appropriate to increase the willingness to make a donation.
- Moreover, number blindness is a common deficit. Percentage calculations are not part of the general knowledge, not even in academics.

  Many people have difficulties to sensibly interpret small probabilities, especially distinguish between the orders of magnitude of such small probabilities (e.g. 10^{-6} versus 10^{-5}). This is not surprising, as such orders of magnitude are outside the range of normal human experience.
- As precarious is the concept of chance of many people. According to them, an essential characteristic of chance is that there are no regular patterns. So many people think that the birth sequence in a family "boy / girl / girl / boy /girl /boy" is chance, but not the sequence "girl / girl / girl /

boy / boy / boy." (I have to admit that these cases are very rare in German families)

- Another issue is the omission bias: It is the tendency to judge harmful actions as worse than equally harmful inactions. One example for this bias is how people deal with "vaccination" Some parents abstain from vaccination, due to the risk of side effects. Unfortunately, they completely ignore the risk caused by the lack of vaccination.
- Associated with this are causal thinking fallacies. This is mainly the "post hoc ergo propter hoc"-fallacy ("after this, therefore because of this").
- In addition, people lean towards the confirmation bias. People prefer looking for cases that confirm their assumptions than for cases that would falsify them.

And, finally, there are – sometimes – quite bizarre attribution patterns. In a recent Austrian study on cancer risk perception, about 25 % of study participants thought that earth radiation and water veins cause cancer. One would probably get similar results in Germany. Esotericism is just popular. Beside these judgemental fallacies there is also the general fear of new things, people fear the risk of the unknown, the unfamiliar and the foreign. But is it always correct? We should remember that the formula that the new and therefore the strange is a risk, is not always true, obviously. And: Being familiar with something is no guarantee of safety. Most murder victims knew their killers. And most accidents occur in the household and on familiar streets.

To avoid misunderstandings: This is no defence of a careless or even happy-go-lucky acceptance of risks. Instead, this is about the proper measure to deal with scientific uncertainty. The media know about these psychological conditions from experience and the media are using them – for instance, when a headline is selected as a lead for a dry news item. No doubt, from the point of attention seeking pictures are better than words, some exaggeration is helpful. So risks are presented in the form of scandalizing stories, where not only the risk, but the involved perpetrators and victims as well as their motivations are described.

The trick is that different presentation (different stories) of an "objective" risk leads to different judgements about the seriousness of the risk, according to the emotion provoked by the story. What follows from this? Yes, media can misinform. It is also true that it is not easy for media to combine simplification with a coverage that is correct. The matters are complicated and the public – the audience of the media – is difficult to satisfy. But that's only part of the truth. Other important players in the drama of mobile phone risk perception were not yet named: science and politics, as well as interest groups and industry.

I would like to start with a few words about science: if science would speak with one voice, there would be no public debate. But this is not the case.

- First, because there is no dogma in science – no undeniable truths.
- Second, scientific dissent is normal for science.
- But there is third aspect. Increasingly extra-scientific interests invade science. On one hand, scientists seek the truth. On the other hand, scientists need money for their research. And they will get it if the research is thought to be necessary for society.

For this, scientists need publicity. However, scientific publishing is slow, and there is good reason for this. So some scientists find sometimes a shortcut: they publish their findings first in the media before they are published in scientific journals. The pressure to do so – and sometimes also the temptation – is huge.

Now for politics: politicians must decide and act. For that reason, they prefer usually scientific certainties and mistrust knowledge gaps and vagueness. They consider cautious scientific phrases like "according to the present state of knowledge" or "in all probability" as political minefields or at least traps. However, we should not forget that uncertainty is sometimes welcomed because it offers room for manoeuvre. In addition, politicians have to consider the vox populi.

And here is the role of media. The politician who ignores the media is at risk himself.

Now, I come to the next topic, the interest groups: In 1994, Jonathan Rauch published a book titled „Demosclerosis. The Silent Killer of American Government", which is worthwhile to read. In contrast with the common view that stakeholder participation is good for democracy, he argues that the number of particular interests in their sum just do not express the common welfare. As you know: The total is more than the sum of its parts. Following Jonathan Rauch, politics is in a fix: it becomes a ritual of improvisation. Every interest group gets something in direct proportion to the political pressure it builds.

At least, we can learn one lesson: participatory decision making is not always the better alternative to democratic decision making. Now for industry: the mobile communication industry, intoxicated by the success, has overlooked the signs of the coming storm. And intoxicated it was indeed, as one can recognize from the exorbitant sums paid at the German UMTS auction. The blitz victory in the expansion of mobile phones seemed to blind the movers and shakers in the telecommunication industry. Now, they try for better solution.

It's now time for conclusions: So, what can we do? First of all. there is no true road to acceptance. In the debate on the risk of mobile telephony, many suggested solutions are right, but as a whole the debate went wrong – as Theodor Adorno says in his "Minima Moralia": "Es gibt kein richtiges Leben im Falschen." ("There is no right life in the wrong one."). And sorry to say, but human beliefs and attitudes can be changed only in a long-term perspective, if at all. And the media system can't change by itself. So where should we begin? I think, a crucial point is the "hysterization" of risk debates, which is wrong in every respect. Our primary goal should be to avoid agitation damage without giving in to indolence. A step forward in this direction would be, not to expect from science what science cannot provide, i.e. 100 % certainty. And scientists should not try to appear more certain than they can be.

Finally, we should recognize that there is no win-win solution for all. It is sometimes a zero sum game. We can only go on, perhaps a little better, but, hopefully, a little less hysterically.

References

- *Adorno, Th. (2001) Minima Moralia. Reflexionen aus dem beschädigten Leben. Frankfurt/M.: Suhrkamp. In English: Minima Moralia: Reflections on a Damaged Life (2006). Verso.*
- *Gigerenzer, G. (2002): Reckoning with risk. London: Penguin Books*
- *Hegel, G.W.F (1821): Grundlinien der Philosophie des Rechts. Naturrecht und Staatswissenschaft, Herausgegeben und eingeleitet von Helmut Reichelt, Ullstein, Frankfurt am Main, 1972. In English: Philosophy of Right (2005), Dover Publications.*
- *Rauch, J. (1994): Demosclerosis. The Silent Killer of American Government. New York: Times Books.*
- *Wallner, P & G. Haidinger , G. (1999): Umwelt und Krebs aus der Sicht der österreichischen Bevölkerung. Bundesgesundheitsblatt. 42, 327-331.*
- *Watzlawick, P.; Weakland, J., Fisch, R. (2000): Lösungen. Zur Theorie und Praxis menschlichen Wandels. Bern: Hans Huber Verlag, 6., unveränderte Auflage.*
- *Watzlawick, P. (1983): Anleitung zum Unglücklichsein. München: Piper.*

Footnote

1 state 7/31/07

Dr. phil. Peter M. Wiedemann is Director of the Programme Group Humans, Environment, Technology at the Research Center Jülich GmbH. One focus of his work is comparative risk assessment and risk communication. He is a member of the „Non-Ionizing Radiation" committee of the Commission for Radiation Protection and member of the editorial boards of international journals on risk research.

Remarks on EMCE of the 15th anniver

by Achim Enders

There has been a considerable increase in resources, i.e. money and research capacities, in the field of EMCE in recent years in Germany and Europe. The German Mobile Telecommunications Research Programme was an important example for that. Likewise 50-Hz magnetic fields are again more intensely addressed in the EMCE debate, as, with the expansion of wind power, the reconstruction and expansion of the energy distribution network to a real energy transport network is needed.

Therefore one can safely assume that much money will be spent for EMCE research also in the future and that the discussion influenced by society, politics and of course also by industry will have a huge influence on funding agencies and the modalities of granting funds again.

Wait a moment, please … yes, you've read correctly. But actually research and science should be more objective than social, political, yes, even democratic debates (that is why already Aristotle knew that science is the least democratic business in the world – measurement values e.g. are not determined by vote). At least there is absolute unanimity regarding this aspect among **all** interest groups: without authentic scientific facts or what is thought to be authentic there is no legitimate standpoint.

This social rationality given in the acceptance of scientific rationale should make it possible that the interest groups being active in the field of EMCE will find answers to the following questions before research funds are provided to them:

1.) There can be no proof of the non-existence of adverse field effects below valid limits. Before new research is funded, a consensus should be reached regarding the remaining risks that can be tolerable – without knowing whether they are real or ficticious. One can spend much money in order to „clarify hypotheses" as they say so nicely in EMCE research programmes – but before there should be clarity about the „remaining unclarity" that is to be accepted. Otherwise all is an end in itself. This is illustrated by my personal observation that also EMCE representatives of the mobile radio industry and network operators act ambivalently on this. On the one hand they refute concrete concerns over health-relevant effects on the basis of the present state of knowledge, on the other hand their job would be cut by their employers, if the risk would be regarded as neglectable from society; moreover we all know that heart-sinking feeling when confronted by aggressive mobile radio critics during public hearings (partially up to real physical threats). The question for clarity primarily shows to be a social and psychological problem. Humans perceive risks in their individual life subjectively. They unconsciously refuse to perceive corresponding statistics as being relevant for their life at all. But: Should research

research on the occasion
sary of the FGF

funds and capacities therefore be used less effectively? The heretical question must be allowed: What could have been done with the funds granted to EMCE research more in other areas for the safety of people?

2.) Should there be biological effects of electromagnetic fields below valid limits, the question is: how could they be uncovered with the best possible probability? Was there a sufficient approach to answer this question in the past?

3.) Associated with question 2.) it may be asked as well, whether, in the case of a reproducible effect, we can assume at all that it is health-relevant. Asked the other way round: What effects would then be health-relevant with high probability?

4.) In view of the heterogeneous results reported by many publications and reviews on biological, biochemical and genetic investigations, also non-experts meanwhile ask: what about quality management? It begins directly with the definition of observed biological endpoints: are they defined clearly and how can they be defined precisely and reproducibly? Are there e.g. standardized round robin tests? There is special cause for concern regarding the question for standardized comparability that has been addressed by some experts for years without being satisfactorily answered. With that in mind, we must state that the exposition measurement technology in the field and in experiments is on one side naturally still a complex issue with imponderabilites, but, on the other side, it is not of central relevance any longer regarding possible future research.

When looking to the future, I would simply wish for more clarity in the EMCE debate: The „clarification“ of real or alleged effects is secondary, first it has to be clear what we want to achieve at all - when looking back, it is indeed amazing that the „electrosmog debate“ is more intense in society than e.g. the „uv debate“, i.e. the risk from solar radiation or of using solariums. In Germany, according to projections from cancer registries, uv radiation is responsible for the majority of the annually new 120,000 skin cancer cases with 5000 deaths. In comparison, the EMCE research is a tool to counter primary fears over risks. The FGF never evaded such partially very uncomfortable questions, and has thereby done more for an objectification than many others. Therefore I would wish that this successful engagement will be continued!

Since 1996 Prof. Dr. rer. nat. habil. Achim Enders is the Director of the Institute for EMC at the Technical University of Braunschweig. Here, he conducts many research projects in the area of radiated EMC, especially in complex traffic carrier systems, as well as electrotechnical basic research.

Imprint

Newsletter of the FGF e.V.

Published by:
Forschungsgemeinschaft Funk e.V.
Rathausgasse 11a, D-53111 Bonn
Phone: 0049-228 - 726 22-0
Fax: 0049-228 - 726 22 11
e-Mail: info@fgf.de
internet: http://www.fgf.de

responsible: Gerd Friedrich

Concept and editing: Daniela Wernze (editor-in-chief), Fred Breit, Uwe Möbius

Copyright: Contributions including the name of the author are protected by copyright and do not necessarily reflect the view of the publishers

Design: Kurt Günther, Dortmund

Layout, graphics:
setz it. Richert GmbH, Sankt Augustin

printed by:
Printec Offset Medienhaus, Kassel; on 100% recycling paper

Illustrations:
p. 13-19, FGF; all others: archive

published 4 times a year

number of copies:
4,000

reprinting and reproduction welcome

ISSN 0949-8745

Disclaimer:
Some of the articles of the FGF Newsletter provide links to external websites. To our knowledge, these external contents were accurate and current at the date of publication. Since internet sites are changeable though, we cannot exclude that contents were changed or deactivated. The responsibility for the content and currency of the linked websites lies with the persons who are legally responsible for the content of the internet pages. The FGF does not warrant or assume any liability regarding material or ideal damage caused by using the links and their contents. We cannot guarantee the accurateness and currency of the linked external websites.